Sound absorption optimization of thin ceiling panels at low frequencies

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1. Project description
2. Experimental investigations & Results
3. Conclusion
4. Future works
Context

✓ Relative inefficiency in low frequencies of suspended ceiling panels (mineral wool) for usual thickness

Objective

✓ Find industrial solutions to improve acoustic absorption at low frequencies (< 200 - 300 Hz)

Restrictions

✓ Thickness, appearance

Evaluated concept

✓ Double porosity
Absorption measurement methods

- Normal incidence
  - Impedance tube Ø 100 mm [50 – 1600 Hz] (NF EN ISO 10534-2)

- Diffuse field
  - Reverberant room [50 – 5000 Hz] (ISO 354)

Absorption prediction methods

- (F)TMM (Finite Transfer Matrix Method)
  - AcouSYS → Normal incidence and diffuse field

- FEM (Finite Element Method) formalism
  - PANAM → Normal incidence

Parameters characterization

- Young modulus E and loss factor η (NF EN 29052-1)
- Air flow resistivity σ (NF EN 29053)
2- Experimental investigations
- Studied system -

❖ Suspended ceiling panel

✓ 3 porous layers

1. Stone wool
   20 mm
   100 kg/m³

2. Front facing:
   White painted veil 0.5 mm
   Highly resistive

3. Rear facing:
   Glass fiber veil 0.2 mm

INTERNOISE 2013| Innsbruck, Austria
2- Experimental investigations - Simple porosity -

- Preliminary results (wool only)

- Good correlation measurements / simulations
  - parameters correctly characterized
- Importance of spatial windowing for TMM simulations (diffuse field)
2- Experimental investigations - Simple porosity -

❖ Influence of front facing (with and without air gap)

- Same trends between measurements and simulations (normal incidence)
- Air gap increases significantly sound absorption over large frequency range
- Opposite effect of the front resistive layer with or without air gap
2- Experimental investigations - Simple porosity -

❖ Influence of the boundaries conditions (complete system)

✓ Crucial importance of boundaries conditions (BC) for normal incidence case with air gap
✓ Further comparisons with measurements using FEM with “embedded condition”
2- Experimental investigations - Concept of double porosity -

❖ Principle

➢ Introducing a second scale porosity through holes or different material
  ✔ Coupling of micropore / macropore media
  ✔ Creating an additional dissipation: pressure diffusion phenomenon

❖ Investigated effect

➢ Material thickness
➢ Front resistive layer and air gap
➢ Perforation rate $\Phi_p = \frac{S_{perfo}}{S_{tot}}$ (number, size)

❖ Resources

➢ Impedance tube (+ PANAM simulations)
➢ Reverberant room (for general validation)
2- Experimental investigations
- Double porosity -

✈ Influence of perforation (wool only)

✈ Good correlation measurements / simulations
✈ Double porosity decreases sound absorption
✈ The larger the perforation rate, the less effective sound absorption
2- Experimental investigations - Double porosity -

**Influence of material thickness** (wool only – Perforation rate 10%)

- Appearance of absorption peak (1) shifting to low frequency when thickness increases
- Increase in sound absorption (1) is offset by significant decrease at low frequencies (2)
- Key role of material thickness for double porosity
2- Experimental investigations
- Double porosity -

❖ Influence of perforation (with an air gap 200 mm)

- Similar trends measurements / simulations
- Sound absorption levels not quite similar
- A large perforation rate \(\Rightarrow\) poor sound absorption
2- Experimental investigations - Double porosity -

- Influence of perforation (complete system)

- Presence of resistive layer with air gap reverses tendencies compared to previous configurations without resistive layer (idem simple porosity)
- With front resistive layer and air gap, large perforation rate improves sound absorption
2- Experimental investigations
- Double porosity -

❖ Influence of perforation number (complete system)

- Increase in perforation number for same perforation rate ➔ limited improvement of sound absorption
2- Experimental investigations
- Double porosity -

- Validation in diffuse field condition (complete system)
  - Perforation rate 20%; 9 holes; Ø 100 mm
  - Good correlation measurement / simulation
  - Effectiveness of double porosity in diffuse field but effect in a limited frequency range (2 zones)

- FTMM SIMULATIONS
  - Ceiling panels + 200mm air gap
  - With perfo. rate 20%
  - Diffuse field measurements
    - Front facing
    - Air gap
    - Wool
Investigations of double porosity effect on sound absorption performance of thin suspended ceilings with and without air gap cavity

Presence of air gap reverses resistive front layer impact on sound absorption

Performance for double porosity system mainly depends on perforation rate

Sound absorption improvement due to double porosity over limited frequency range (depending on system properties)

Correlations between measurements / simulations with CSTB softwares are overall satisfactory
4- Future work

 ✓ Continue investigating double porosity on multi-perforated panels in reverberant room

 ✓ Develop parametric characterization benches (porous materials)
   • Impedance tube Ø45 mm (3 microphones indirect method)
   • Porosimeter,
   • Microscopic analysis, …

 ✓ Include double porosity materials in TMM based software (AcouSYS)
Thank you for your attention