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Prediction method for lightweight constructions acoustic performance

COST FP0702 - WG1

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Introduction

Research work over the last years regularly presented within this COST action

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Discussions within this COST action

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Global contours emergence for an approach to predict sound transmission for lightweight buildings systems

Approach based on refining and adjusting the model in EN 12354 in order to fit the specifics of lightweight building systems

Practical method on an engineering level

Preparation for proposals to CEN/TC126/WG2 to amend EN 12354

Model Description EN12354 bases

From power transmission and reciprocity
Flanking transmission factor τ_{ij} for path from element i to element j

$$\tau_{ij} = \tau_{r,i} d_{s,ij} \frac{\sigma_{r,j}}{\sigma_{r,i}} \frac{S_j}{S_s}$$

$$\tau_{ij} = \sqrt{\tau_{r,i}\tau_{r,j}} \sqrt{d_{s,ij} d_{s,ji}} \frac{\sqrt{S_i S_j}}{S_s}$$

- **Subscript *r* for resonant vibrations**
- **Subscript s for structural excitation**
- **τ transmission factor**
- **d_{ij} average vibration ratio between excited element i and element j**
- **σ radiation factor**
- ***S* surface**

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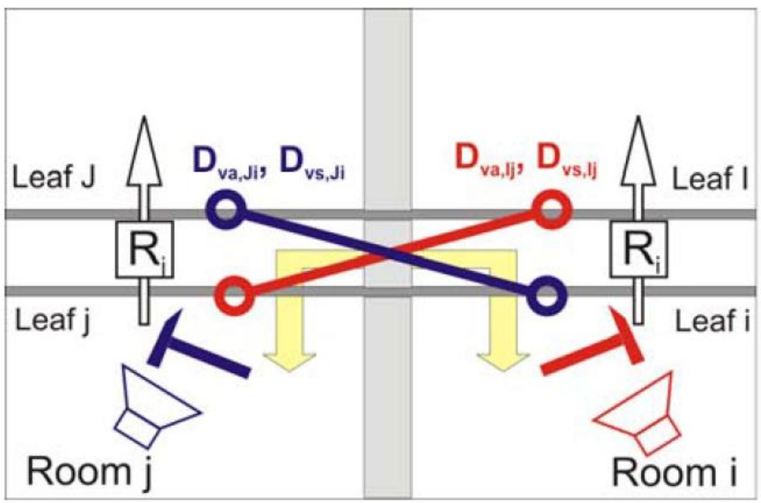
Model Description EN12354 bases

SPECIAL ATTENTION REQUIRED

which element is to be considered in predictions
double element as a whole or just inner leaf, single or multilayered

All possible in combination with appropriate $D_{v,ij}$

Choice depending on type of input data available



From Schoenwald, Euronoise 2012

Double element as a whole : sound reduction index measured, but $D_{v,ij}$ measurements to be adjusted

Just the inner leaf : $D_{v,ij}$ measurements more straight forward, but extra measurement for sound reduction index of inner leaf only

Sound reduction index R for resonant transmission

Consider only resonant transmission in flanking path

↓

Need to know *R* of element for resonant transmission only

$D_{v,ij}$ also for resonant transmission only
→ $D_{vs,ij}$ determined by mechanical excitation

Sound reduction index *R* for resonant transmission based
on pure calculation
or laboratory measurements (ISO 10140)

R for resonant transmission Calculation

For homogeneous elements : Annex B in EN 12354-1 with some minor adjustment

For more complex elements : other models from literature, possibly based on SEA for layered elements

⚠ **With commercially available models not always possible to delete forced transmission**

Recent research
reliable predictions for resonant transmission are hardly possible at present due to insufficient estimates of radiation efficiencies and/or actual damping in lightweight elements

Approach not recommended for lightweight elements

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R for resonant transmission From measurement

$$R_{lab}^{*} = R_{lab} + 10\lg\left[1 + \frac{\sigma_f}{\sigma_r}\frac{\sigma_a - \sigma_r}{\sigma_f - \sigma_a}\right] \approx R_{lab} + 10\lg\frac{\sigma_a}{\sigma_s}\frac{1-\sigma_s}{1-\sigma_a} \approx R_{lab} + 10\lg\frac{\sigma_a}{\sigma_s}$$

σ_f and σ_r
radiation efficiency for forced and resonant transmission (theory)

σ_a and σ_s
radiation efficiency with airborne and structural excitation (measurement)

Assumption $\sigma_r = \sigma_s$ and $\sigma_f \approx 1$

Further approximation due to limited available data
Most recent measurements for double elements :
correction negligible $\Rightarrow$ correction 0 dB

For single, homogeneous or layered elements :
correction reasonably independent of element type
$\Rightarrow$ ~ 8 to 10 dB below critical frequency

Overall performance per transmission path

In lightweight building systems, elements normally with larger damping and vibration levels less effected by energy losses at borders

Laboratory sound reduction index mainly determined by internal damping and thus independent form situation in which it is built into

Results for overall flanking transmission in one laboratory / situation transferable to other situations

$$R_{ij} = D_{nf} + 10\lg \frac{S_s l_{ij,lab}}{A_0 l_{ij}} \qquad L_{n,ij} = L_{nf} - 10\lg \frac{S_i l_{ij,lab}}{S_{i,lab} l_{ij}}$$

l_{ij} coupling length and S_i excited area in field situation
$l_{ij,lab}$ coupling length and $S_{i,lab}$ excited area in laboratory situation

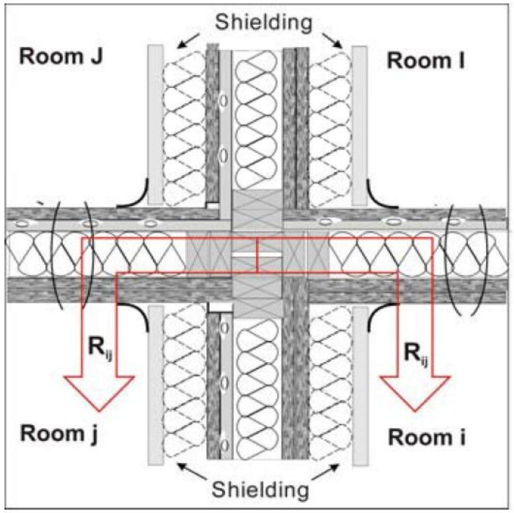
Direct measurement of flanking path

ISO 10848 ⇒ D_{nf} ,L_{nf} measurements in dedicated lab facilities for Ff path

For lightweight building, other flanking paths, Fd or Df, can have considerable contribution

Measurements of D_{nf} and L_{nf} for Fd or Df flanking paths
⇒ practical problem :
other paths than one studied must be reduced by linings
Shielding has limited performance in low frequency range

Approach used in several laboratories :
- **NRC, Canada**
- **EMPA, Switzerland**
- **BBRI, Belgium**



From Schoenwald, Euronoise 2012

Hybrid approach for evaluating flanking path

Flanking transmission estimated from combination of measured and calculated data

$$D_{nf} = \frac{R^*_i}{2} + \frac{R^*_j}{2} + \Delta R_i + \Delta R_j + \overline{D_{v,ij,n}} + 10\lg\frac{A_o}{l_{ij,lab}}$$

$$L_{nf} = L_{n,ii} + \frac{(R^*_i - R^*_j)}{2} - \Delta L_i - \Delta R_j - \overline{D_{v,ij,n}} - 10\lg\frac{S_{i,lab}}{l_{ij,lab}}$$

Advantage :

effect of changes in elements, linings, junctions more easily evaluated

New junction quantity $\overline{D_{v,ij,n}}$

actually similar to K_{ij} from ISO 10848 and EN 12354 with standardization to area

Renewed definition K_{ij}

With damped elements, standardization on damping is not necessary
Structural reverberation time is relevant
Attenuation over distance is what should be taken into account

$$\overline{D_{v,ij,n}} = \frac{D_{v,ij}}{2} + \frac{D_{v,ji}}{2} + 10\lg\frac{l_{ij}}{\sqrt{S_{m,i}S_{m,j}}}$$

$S_{m,i}$ and $S_{m,j}$ are measurement areas, equal or smaller than element areas
If areas are not too small, result independent of actual area

$$\overline{D_{v,ij,n}} \approx K_{ij,junction} + 10\lg\sqrt{\delta_i \delta_j}$$

$K_{ij,junction}$ estimated by taking into account structural reverberation times for reasonable homogeneous elements
δ_i average extra attenuation in dB per meter, over the geometric spreading of element

Determining δ from measurements could be added to measurement standard ISO 10848

Service equipment noise

Similar approach for sound due to service equipment but for one aspect

**Piece of equipment mostly excites structure
at one point or small area only
not random over the element as with tapping machine**

**Excitation point in relation to junction, studs/joists
can be important in case of well damped elements**

**Adjustment terms for that
currently studied and proposed but need further attention**

Conclusions
WG1 achievement

- **Proposal for prediction method based on refining and adjusting model in EN 12354 in order to fit specifics of lightweight building systems**
- **Practical method on engineering level**
- **Service equipment noise prediction method still under development**

- **Needs identification for standards updates, especially concerning measuring input parameters necessary in prediction method**