Flanking Transmission

J. NEGREIRA
DIVISION OF ENGINEERING ACOUSTICS, LUND UNIVERSITY
Outline

- Introduction
- Flanking transmission
  - Examples
- Summary
- Airborne: SS-EN 12354-1
- Impact: SS-EN 12354-2
References: SS-EN 12354 series

Introduction (I)

• Sound transmission
  – Airborne
  – Structure-borne
• Transmission paths
  – Direct transmission \((D)\)
  – Flanking paths \((F_i)\)

• Flanking: cause of problems related with acoustic comfort
  – Difference between lab and in-situ measurements \(\sim 4\) dB
    » Estimation methods described in SS-EN 12354:2000
    – Acoustic performance as sum of individual contributions
Introduction (II)

Laboratory measurements $\rightarrow$ good control $\rightarrow$ “just” direct transmission

In reality, more transmission paths

\[
R = 10 \cdot \log \left( \frac{\Pi_i}{\Pi_f} \right) = 10 \cdot \log \left( \frac{1}{\tau} \right) \quad \text{[dB]}
\]

\[
\tau = \frac{\Pi_f}{\Pi_i}
\]

- Direct
- Flanking
- Parts added to wall (windows, doors, leaks...)
  May be included in $\tau_d$
- Indirect transmission between rooms (ducts, suspended ceiling...)

\[
R' = 10 \cdot \log \left( \frac{1}{\tau'} \right) \quad \text{[dB]}
\]
Introduction (III)

\[ \tau' \approx \tau_d + \tau_f \]

\[ \tau_d = \tau_{Dd} + \sum_n \tau_{Fd} \]

\[ \tau_f = \sum_m \tau_{Df} + \sum_k \tau_{Ff} \]

**NOTES:** The sketch only indicates first-order paths; paths involving one element in the sending room, one junction or connection and one element in the receiving room. // The number of elements \( n, m \) and \( k \) are normally 4. // Main contributions are normally the \( Ff \) paths.
Outline

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Airborne: SS-EN 12354-1

Flanking transmission

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Impact: SS-EN 12354-2
Flanking transmission reduction index (I)

- Apparent sound reduction index (13 paths)

\[ R'_w = -10\log \left[ \frac{-R_{Dd,w}}{10} + \sum_{F=f=1}^{n} 10 \frac{-R_{Ff,w}}{10} + \sum_{f=1}^{n} 10 \frac{-R_{Df,w}}{10} + \sum_{F=1}^{n} 10 \frac{-R_{Fd,w}}{10} \right] \]

- If only \( Ff \) paths are assumed:

\[ R'_w = -10\log \left[ \frac{-R_{d,w}}{10} + \sum_{f=1}^{n} 10 \frac{-R_{f,w}}{10} \right] \]
Flanking transmission reduction index (II)

- Flanking sound reduction index $R_{ij}$ (approximation given in the standard SS-EN 12354-1)

$$
(R_f)_{ij,w} = R_{ij,w} = \frac{R_{i,w} + R_{j,w}}{2} + K_{ij} + 10 \log \left( \frac{S_s}{l_0 \cdot l_{ij}} \right)
$$

$R_i$ & $R_j$: sound reduction index of flanking element $i$ and $j$

$K_{ij}$: vibration reduction index (junction dependent)

$S_s$: floor / wall surface

$l_0 = 1m$

$l_{ij}$: junction common length

**NOTES:** $K_{ij}$ is related to the vibrational power transmission over a junction between structural elements under diffuse field conditions, normalised in order to make it an invariant quantity (independent of the energy losses). This quantity can be taken from Annex E of SS-EN 12354-1. // An additional term $+\Delta R_{ij}$ would be added to the right hand side of the equation to account for improvement of sound reduction due to additional linings (here is omitted).
Flanking transmission reduction index (III)

- Vibration reduction indexes $K_{ij}$
  - SS-EN 12354-1:2000 (Annex E)

$K_{13} = 8.7 + 17.1 M + 5.7 M^2$ dB / octave
$K_{12} = 8.7 + 5.7 M^2 (= K_{23})$ dB / octave

$K_{13} = 5.7 + 14.1 M + 5.7 M^2$ dB / octave
$K_{12} = 5.7 + 5.7 M^2 (= K_{23})$ dB / octave
Flanking transmission reduction index (IV)

- Vibration reduction indexes $K_{ij}$
  - SS-EN 12354-1:2000 (Annex E)

\[ K_{13} = 5.7 + 14.1M + 5.7M^2 + 2\Delta_1 \text{ dB} \]
\[ K_{23} = 3.7 + 14.1M + 5.7M^2 \text{ dB} ; 0 \leq K_{23} \leq -4 \text{ dB} ; 0 \text{ dB / octave} \]
\[ K_{12} = 5.7 + 5.7M^2 + \Delta_1 \text{ dB (} = K_{21}) \]
\[ \Delta_1 = 10 \log \frac{f}{f_1} \text{ dB for } f > f_1 \]
\[ f_1 = 125 \text{ Hz if } \frac{\sigma_1}{f_1} = 100 \text{ MN/m}^3 \text{ ; see text} \]

\[ K_{13} = 5 + 10 \text{ M dB and minimum 5 dB ; 0 dB / octave} \]
\[ K_{12} = 10 + 10 \text{ M (} - K_{23}) \text{ dB ; 0 dB / octave} \]
\[ a_{f_{acacia}} = \Delta_{f_{f_{acacia}}} / f_0 \]
Flanking transmission reduction index (V)

- Vibration reduction indexes $K_{ij}$
  - SS-EN 12354-1:2000 (Annex E)

\[ K_{13} = 10 \times 20 M - 3.3 \frac{f}{f_k} \text{ dB and minimum 10 dB} \]
\[ K_{12} = 10 \times 10 M - 3.3 \frac{f}{f_k} \text{ dB} \quad (= K_{23}) \]
\[ f_k = 500 \text{ Hz} \quad \alpha_{im} = S/l_s \]
\[ K_{24} = 3.0 - 14.1 M + 5.7 M^2 \frac{f}{f_k} \text{ dB} \quad \frac{m_2}{m_1} > 3 \text{ dB / octave} \]
\[ K_{12} = 10 \times 10 M + 3.3 \frac{f}{f_k} \text{ dB} \quad (= K_{23}) \]
\[ f_k = 500 \text{ Hz} \quad \alpha_{	ext{lightweight wall, slt}} = \text{Slightweight wall } / l_s \]
Flanking transmission reduction index (VI)

- Vibration reduction indexes $K_{ij}$
  - SS-EN 12354-1:2000 (Annex E)

![Diagram showing corner or thickness change with formulas for $K_{12}$ and $K_{21}$]
Outline

Introduction

Airborne: SS-EN 12354-1

Flanking transmission

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Impact: SS-EN 12354-2
Impact sound with flanking transmission (I)

- Impact sound pressure level in the receiving room

\[ L'_n = 10 \log \left( 10^{\frac{L_{n,d}}{10}} + \sum_{j=1}^{n} 10^{\frac{L_{n,ij}}{10}} \right) \]

- If the SS-EN 12354-1 simplified model is assumed, the weighted normalised impact sound pressure level is:

\[ L'_{n,w} = L_{n,w,eq} - \Delta L_w + K \]

\[ L_{n,w,eq} = 164 - 35 \log \left( \frac{m'}{m_0'} \right) \]

\[ m_0' = 1 \text{ kg} / \text{m}^2 \]

**NOTES:**
- K is the correction for impact sound transmission over the homogeneous flanking constructions in decibels, and it is given in a tabular form in the standard. // Limitations: the simplified model is only applied to homogeneous building constructions with floating floors or soft coverings on a homogeneous constructions, and only for rooms one above each other which are of conventional sizes in dwellings.
# Impact sound with flanking transmission (II)

## Table 1 - Correction $\kappa$ for flanking transmission in decibels

| Mass per unit area of the separating element (floor) in $\text{kg/m}^2$ | Mean mass per unit area of the homogeneous flanking elements not covered with additional layers in $\text{kg/m}^2$ |
|---|---|---|---|---|---|---|---|---|---|
| 100 | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 |
| 100 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 150 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 200 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 250 | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 300 | 3 | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 350 | 3 | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 400 | 4 | 2 | 2 | 1 | 1 | 1 | 0 | 0 | 0 |
| 450 | 4 | 3 | 2 | 2 | 1 | 1 | 1 | 1 | 1 |
| 500 | 4 | 3 | 2 | 2 | 1 | 1 | 1 | 1 | 1 |
| 600 | 5 | 4 | 3 | 2 | 2 | 1 | 1 | 1 | 1 |
| 700 | 5 | 4 | 3 | 3 | 2 | 2 | 1 | 1 | 1 |
| 800 | 6 | 4 | 4 | 3 | 2 | 2 | 2 | 1 | 1 |
| 900 | 6 | 5 | 4 | 3 | 3 | 2 | 2 | 2 | 2 |

If one or more massive flanking constructions are covered by additional layers (wall lining) with a resonant frequency $f_0 < 125 \text{ Hz}$ according to D.2 of EN 12354-1 : 2000 the surface masses of the covered elements are not considered in the calculation of the mean mass value.

**NOTE** In principle a correction term $\kappa$ to express the contribution of flanking transmission could also be derived for other room configurations than rooms above each other.
NOTES: The weighted reduction of impact sound pressure level $\Delta L_w$ depends on the mass per unit area $m'$ of the floating floor and the dynamic stiffness per unit area $s'$ of the resilient layer according to EN 29052-1.
Outline

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Airborne: SS-EN 12354-1

Flanking transmission

Calculation

Examples

Impact: SS-EN 12354-2

Design

Summary
Calculation example 1 (SS-EN 12354-1:2000)

Key

A  Ground plan
B  Sectional view

Separating element:
1  wall 4,50 m × 2,55 m = 11,5 m²; 200 mm concrete, 460 kg/m².

Flanking elements (identical on both sides):
2  Façade: 4,36 m × 2,55 m = 11,1 m²; rigid T junction; 100 mm calcium-silicate blocks, 175 kg/m².
3  Internal wall: 4,36 m × 2,55 m = 11,1 m²; cross junction with elastic layer; 70 mm gypsum blocks, 67 kg/m².
4  Ceiling: 4,36 m × 4,50 m = 19,6 m²; rigid cross junction; 100 mm concrete, 230 kg/m².
5  Floor: 4,36 m × 4,50 m = 19,6 m²; rigid cross junction; 100 mm concrete / 30 mm finish, 287 kg/m².
6  flexible connection
Calculation example 1 (SS-EN 12354-1:2000)

**Data:**

<table>
<thead>
<tr>
<th>INPUT DATA :</th>
<th>ELEMENTS</th>
<th>JUNCTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$m'$ (kg/m$^2$)</td>
<td>$R_w$ (dB)</td>
</tr>
<tr>
<td>Wall (s)</td>
<td>460</td>
<td>57</td>
</tr>
<tr>
<td>Floor ($F = f = 1$)</td>
<td>287</td>
<td>49</td>
</tr>
<tr>
<td>Ceiling ($F = f = 2$)</td>
<td>230</td>
<td>46</td>
</tr>
<tr>
<td>Façade ($F = f = 3$)</td>
<td>175</td>
<td>42</td>
</tr>
<tr>
<td>Internal wall ($F = f = 4$)</td>
<td>67</td>
<td>33</td>
</tr>
</tbody>
</table>

**Solution:**

Wall:
- $R_{Dw} = 57,0$ dB
- $R_{1d} = 49/2 + 57/2 + 8,9 + 4,1 = 66,0$ dB
- $R_{2d} = 46/2 + 57/2 + 9,2 + 4,1 = 64,8$ dB
- $R_{3d} = 42/2 + 57/2 + 6,7 + 6,5 = 62,7$ dB
- $R_{4d} = 33/2 + 57/2 + 15,7 + 6,5 = 67,2$ dB

Floor:
- $R_{D1} = 49/2 + 57/2 + 8,9 + 4,1 = 66,0$ dB
- $R_{1f} = 49 + 12,4 + 4,1 = 65,5$ dB

Ceiling:
- $R_{D2} = 46/2 + 57/2 + 9,2 + 4,1 = 64,8$ dB
- $R_{22} = 46 + 14,4 + 4,1 = 64,5$ dB
- $R_{33} = 42 + 12,6 + 6,5 = 61,1$ dB
- $R_{44} = 33 + 33,5 + 6,5 = 73,0$ dB

Façade:
- $R_{D3} = 42/2 + 57/2 + 6,7 + 6,5 = 62,7$ dB
- $R_{33} = 42 + 12,6 + 6,5 = 61,1$ dB

Internal wall:
- $R_{D4} = 33/2 + 57/2 + 15,7 + 6,5 = 67,2$ dB
- $R_{44} = 33 + 33,5 + 6,5 = 73,0$ dB

**Total (equation 26)**

$$R_w' = 52,2 \approx 52$$ dB
Calculation example 2 (SS-EN 12354-2:2000)

• Task:

The impact sound pressure level $L'_n$ between two dwellings is to be calculated for two rooms above each other, separated by a concrete floor slab covered with a floating floor. The volumes of the rooms are 50 m$^3$, the other construction details are given below.

**Separating element:**

floor  
$S_i = 5,00 \text{ m} \times 4,00 \text{ m} = 20,0 \text{ m}^2$;

140 mm concrete, $m' = 0,14 \text{ m} \times 2300 \text{ kg/m}^3 = 322 \text{ kg/m}^2$;

floating floor:  
35 mm concrete on 20 mm mineral wool slab with $s' = 8 \text{ MN/m}^3$.

**Flanking elements (identical on both sides):**

internal walls  
$S_j = 5,00 \text{ m} \times 2,50 \text{ m} = 12,5 \text{ m}^2$; rigid cross junction;

120 mm aerated concrete, $m' = 0,12 \text{ m} \times 800 \text{ kg/m}^3 = 96 \text{ kg/m}^2$;

external walls  
$S_j = 4,00 \text{ m} \times 2,50 \text{ m} = 10,0 \text{ m}^2$; rigid T junction;

100 mm brickwork, $m' = 0,1 \text{ m} \times 1900 \text{ kg/m}^3 = 190 \text{ kg/m}^2$. 
Calculation example 2 (SS-EN 12354-2:2000)

• Solution:

  — equivalent weighted normalized impact sound pressure level of the concrete floor slab: from annex B:

  \[ L_{n,w,eq} = 164 - 35 \log(m'/m'_o) \text{ with } m'_o = 1 \text{ kg/m}^2 \]
  \[ = 164 - 35 \log (322/1) = 76.2 \text{ dB} \approx 76 \text{ dB} \]

  — weighted impact sound improvement index of the floating floor:

  with the dynamic stiffness per unit area \( s' = 8 \text{ MN/m}^3 \) of the mineral wool slab and the mass per unit area \( m' = 80 \text{ kg/m}^2 \) of the floor screed follows from Figure C.1:

  \[ \Delta L_w = 33 \text{ dB} \]

  — correction \( K \) for flanking transmission:

  mean surface mass of the homogeneous flanking elements, not covered with resilient layers, \( m' = 0.25 \left( (2 \times 190) + (2 \times 96) \right) \text{ kg/m}^2 = 145 \text{ kg/m}^2 \); so from Table 1:

  \[ K = 2 \text{ dB} \]

  — weighted normalized impact sound pressure level between the two rooms:

  from equation (21):

  \[ L'_{n,w} = L_{n,w,eq} - \Delta L_w + K = (76 - 33 + 2) \text{ dB} = 45 \text{ dB} \]
Design example: decoupling structural elements
Design example: timber volume elements
Design example: elastic interlayers
Outline

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Flanking transmission

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Airborne: SS-EN 12354-1

Impact: SS-EN 12354-2
Summary (I)

- Flanking transmission (airborne)

\[ R'_{w,\text{total}} = R'_{w} + C_{50-3150} \]

\[ R'_w = -10 \log_{10} \left[ 10^{R'_{Dd,w}} + \sum_{f=1}^{n} 10^{R'_{Ff,w}} + \sum_{f=1}^{n} 10^{R'_{Df,w}} + \sum_{F=1}^{n} 10^{R'_{Fd,w}} \right] \]

\[ C_{50-3150} = -10 \log_{10} \left( \sum_{i} 10^{\frac{L_i - R_i}{10}} \right) - R'_w \]

\[ \left( R'_f \right)_{ij,w} = R_{ij,w} = \frac{R_{i,w} + R_{j,w}}{2} + K_{ij} + 10 \log_{10} \left( \frac{S_s}{l_0 \cdot l_{ij}} \right) \]
Summary (II)

- Flanking transmission (impact)

\[
L'_n = 10 \log \left[ 10^{\frac{L_{n,d}}{10}} + \sum_{j=1}^{n} 10^{\frac{L_{n,ij}}{10}} \right]
\]

\[
L'_{n,w} = L_{n,w,eq} + \Delta L_w + K
\]

\[
L_{n,w,eq} = 164 - 35 \log \left( \frac{m'}{m_0'} \right)
\]

\[
m_0' = 1 \text{kg/m}^2
\]

Figures in SS EN12354-2

Table in SS EN12354-2
Thank you for your attention!

juan.negreira@construction.lth.se