Technical note No 40

Sound environment behind a building envelope

This Technical Note is one of four on building envelope acoustics. The series comprises:

- TN 37 Introduction to building envelope acoustics
- TN 38 Acoustic performance of windows
- TN 39 Sound transmission through building envelopes
- TN 40 Sound environment behind a building envelope

This Technical Note is not a guide to the acoustic design of rooms. It provides guidance on the influence of the room on the envelope performance.

Introduction

This Technical note deals with the sound environment in a room behind a façade. It considers sources of sound external to the room, sound sources within the room and sound absorption within a room.

Sound may also be transmitted into a room from an adjacent or remote room as structure borne sound, for instance the sound of tapping on a mullion or transom in another room.

The reader should be familiar with Technical Notes 37, 38 and 39 in order to apply the advice given in this Technical Note.

Principles

The sound environment in a room will depend on:

- Sound sources external to the room,
- Sound sources within the room,
- Sound absorption within the room

The façade will contribute to the acoustic quality of the room by:

- Limiting direct airborne sound transmission from the external environment,
- Limiting air flanking transmission between the room and adjacent rooms,
- Modifying the sound absorption of the room.

Glass screens and lightweight walls are generally more flexible, and absorb more sound than heavy and rigid surfaces such as concrete floors or walls covered with a dense plaster.

Glass screens and lightweight walls are lighter than other forms of construction and having less mass transmit more sound than heavier constructions.

The acoustic performance of a façade and the acoustic environment within a room depend on the frequency content of the sound sources involved. Analysis of either should be undertaken by considering the performance at each octave (or preferably third octave) band (TN 37).

External noise

Transmission of sound through the building envelope is described in TN 39. One way of reducing the sound levels due to external sound is to improve the apparent sound reduction index of the facade.

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Noise in adjacent rooms

Noise from adjacent rooms, above, below or alongside the room, will be transmitted by:

- Direct transmission through the separating walls
- Flanking transmission:
  - Between the separating walls and the façade
  - Through the framing members of the wall

To prevent airborne sound transmission it may be desirable to design the façade with suitable internal surfaces or rebates for the internal walls to interface with the façade.

To prevent structure borne sound transmission through members such as mullions and transoms it may be possible to structurally isolate mullions and transoms at the room boundaries. However, this can be difficult to achieve and some designers fill the mullions with sand to modify the vibration characteristics of the aluminium profile.

Sound sources in a room

Sound sources within a room will contribute to the sound level in that room. The presence of sound sources within the room, although they may increase the sound level, may help to mask the external noise and noise from adjacent rooms. Conversely in a room with no internal sound sources, external sounds may be more audible, even those with a low sound pressure level (SPL).

Sound level in a room

The sound level in a room will comprise both direct sound and reflected sound. The contribution from the reflected sound can be reduced by introducing surfaces that absorb sound (Reduce the level of reflected sound).

Sound absorption

The sound level in a room is affected by sound absorption within the room.

Different surfaces have different absorption coefficients \( \alpha \).

\[
\alpha = \frac{\text{reflected energy}}{\text{incident energy}}
\]

The level of reflected sound in a room depends on the total sound energy absorption of the room, \( A \).

\[
A = S_1 \alpha_1 + S_2 \alpha_2 + \ldots = \sum S_i \alpha_i
\]

Where:

\( S = \text{Area of surface} \)
\( \alpha = \text{Absorption coefficient of surface} \)

<table>
<thead>
<tr>
<th>Material</th>
<th>125 Hz</th>
<th>500 Hz</th>
<th>2 kHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carpet</td>
<td>0.03</td>
<td>0.25</td>
<td>0.33</td>
</tr>
<tr>
<td>Plaster</td>
<td>0.01</td>
<td>0.02</td>
<td>0.03</td>
</tr>
<tr>
<td>Glass</td>
<td>0.10</td>
<td>0.05</td>
<td>0.02</td>
</tr>
<tr>
<td>Acoustic tile</td>
<td>0.35</td>
<td>0.40</td>
<td>0.80</td>
</tr>
</tbody>
</table>

Table 1 Absorption coefficients for different surfaces

Sound level in a room due to external noise

The sound level in a room from a source external to the room is given by:

\[
L_{in} = L_{out} - R + 10 \log \left( \frac{S}{A} \right) + x \text{ dB}
\]

Where:

\( L_{in} = \text{Internal sound level} \)
\( L_{out} = \text{External sound level} \)
\( R = \text{Sound reduction index of external wall} \)
\( S = \text{Surface area of wall} \)
\( A = \text{Total acoustic absorption of wall} \)
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\[ x = \text{Correction for diffusion of external sound} \]

**Sound source** \( x \)

- Noise external to the building (point source) \( 6 \)
- Traffic noise (line source) \( 3' \)
- Noise in an adjacent room (fully diffuse) \( 0 \)

\*Some acoustic consultants take a value of 6 for all external noise.*

Table 2 Diffusion correction factors

This sound level has to be combined with the sound levels of the other sources contributing to the sound level in the room to obtain the actual sound level in the room, (See TN 37).

**Benefit of absorbing surfaces to reduce sound levels**

As a result of the logarithmic relationship in the above equation, increasing the area of sound absorbing material does not always have a great effect. The table below shows the level of reflected sound for a cubic room with different surface treatments.

<table>
<thead>
<tr>
<th>Surfaces</th>
<th>Reflected sound</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 hard</td>
<td>18.3 dB</td>
</tr>
<tr>
<td>5 hard + carpet</td>
<td>13.5 dB</td>
</tr>
<tr>
<td>5 hard + acoustic tiles</td>
<td>11.9 dB</td>
</tr>
<tr>
<td>4 hard + carpet + acoustic tiles</td>
<td>10.2 dB</td>
</tr>
</tbody>
</table>

Assuming sound of frequency 500 Hz

Table 3 Reflected sound levels for different rooms

Adding either the carpet alone or the acoustic tiles alone noticeably reduces the level of reflected sound. Adding the acoustic tiles in addition to the carpet makes less than 2 dB difference in sound level, an effect that is probably not noticeable.

**Specifying the acceptable internal sound levels**

BS 8233 makes recommendations for acceptable sound levels in rooms containing different activities, Table 4.

Advice on internal sound levels specific to schools is available in Building Bulletin 93.

<table>
<thead>
<tr>
<th>Space</th>
<th>( L_{AEQ,T} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dwellings</td>
<td></td>
</tr>
<tr>
<td>Living room</td>
<td>30-40</td>
</tr>
<tr>
<td>Bedroom</td>
<td>30-35</td>
</tr>
<tr>
<td>Offices</td>
<td></td>
</tr>
<tr>
<td>Private offices</td>
<td>35-40</td>
</tr>
<tr>
<td>Large office</td>
<td>40-50</td>
</tr>
<tr>
<td>Teaching spaces</td>
<td></td>
</tr>
<tr>
<td>Classroom</td>
<td>35-40</td>
</tr>
<tr>
<td>Lecture theatre</td>
<td>30-35</td>
</tr>
<tr>
<td>Other</td>
<td></td>
</tr>
<tr>
<td>Cafeteria</td>
<td>50-55</td>
</tr>
<tr>
<td>Light workshop</td>
<td>65-75</td>
</tr>
</tbody>
</table>

Table 4 Recommended internal sound levels from BS 8233

**Reverberation**

Reverberation occurs in rooms due to repeated reflections off the walls, floor and ceiling. A room with predominantly absorbent surfaces will have reduced sound levels but it may be more difficult to hear speech clearly. Conversely a room with predominantly reflective surfaces will have a long reverberation time, such as a cathedral. In such a room it is easier to hear speech but ambient sound levels are higher and speech may be less intelligible.

The time it takes for the sound level to decay by 60 dB is the reverberation
time. Sabine’s equation for reverberation time is:

\[ T = \frac{0.16v}{A} \]

Where:

- \( T \) = Reverberation time (Seconds)
- \( v \) = Room volume (m\(^3\))
- \( A \) = Total acoustic absorption

Recommended reverberation times for different activities are shown in Table 5.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Reverberation time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic living room</td>
<td>0.5</td>
</tr>
<tr>
<td>Lecture theatre</td>
<td>0.7 – 1.0</td>
</tr>
</tbody>
</table>

Table 5  Recommended reverberation times for different activities

Any attempts to modify the reverberant sound level due to an external sound source by modifying the sound absorption of a room must take account of reverberation time. This will involve the client’s design team and usually a consultant acoustician. Reverberation times for a room of floor 5m x 4m and 2.5m height with different wall treatments are shown in Table 6.

It should be noted that sound absorption will be greatly affected by the contents of the room including furnishings and occupants. Reverberation times of an occupied room will be less than those shown in Table 6.

It is wrongly believed by some people that glass is a hard surface but glass is flexible and is a better sound absorber than surfaces such as concrete floors and plastered walls, particularly at lower frequencies. The effect of this in a room will depend on the other surfaces of the room and may not be significant.

<table>
<thead>
<tr>
<th>Surfaces</th>
<th>Reflected sound</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 hard + 1 glass</td>
<td>5.58 s</td>
</tr>
<tr>
<td>5 hard + windows + 1 carpet</td>
<td>2.14 s</td>
</tr>
<tr>
<td>4 hard + 1 glass + 1 carpet</td>
<td>2.25 s</td>
</tr>
<tr>
<td>4 hard + 1 glass + 1 acoustic tiles</td>
<td>1.53 s</td>
</tr>
<tr>
<td>3 hard + 1 glass + 1 carpet + 1 acoustic tiles</td>
<td>1.06 s</td>
</tr>
</tbody>
</table>

Table 6  Reverberation times of an empty room for different room treatments

Particular problems of reflected sound

Reflected sound can be a particular problem when room surfaces are curved. In particular low glass domes or barrel vaults may place occupants at the focal point of the curved surface where they hear an excessive amount of sound.

Responsibility for acoustic performance of a facade

The wall designer/contractor cannot deliver a particular internal sound level as that will be influenced by fit out of the room and occupancy.

If walls are required to provide a particular sound reduction they should be specified by stating the required sound reduction index of the wall at different frequencies (normally third octave bands).

Any requirements to limit flanking transmission have to be stated by the specifier. The façade contractor may need to agree with any internal partition contractor how to detail interfaces between the faced and internal partitions.

Any requirement to limit structure borne sound through the framing members of the wall should be stated by the Specifier.
Best value for the Client will normally be attained by considering the cladding options and calculating the sound levels in the room for each solution. The different acoustic performances can then be evaluated against the costs of construction.

Early consultation between the façade contractor, architect and any retained acoustic consultant is essential to achieve an economic solution that balances the room design and façade design.

**Standards**

Building construction. Expression of users' requirements. Acoustical requirements

**BS 8233:1999**
Sound insulation and noise reduction for buildings. Code of practice

**Bibliography**


