Datasheet III.5.2

Prepared by: L. Bragança[1], J. Patrício[2]

[1] University of Minho

[2] National Laboratory for Civil Engineer

Portugal

ACOUSTIC ASSESSMENT OF MIXED BUILDING TECHNOLOGY SOLUTIONS

Introduction

- Sound can be defined as the propagation of pressure and depression waves the human ear can detect.
- If a wall is submitted to pressure and depression waves it will vibrate emitting a sound with a frequency equal to that emitted by the source. This transmission of sound depends on the acoustic energy that hits the wall and on its interior structure (Meisser, 1978).
- In building acoustics two main types of sound propagation can be considered: the airborne sound and the structure borne sound (normally known as impact sound).
- In what respects airborne sound, there are three main transmission paths between adjacent rooms (Figure 1):
    - 1. Direct transmission through joints, discontinuities and cracks;
    - 2. Direct transmission due to the vibration of the partition itself; and
    - 3. Flanking transmission.

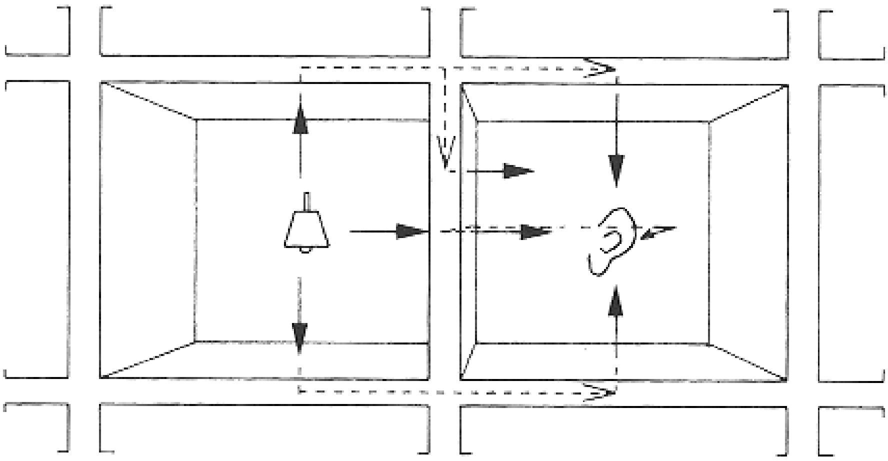


Figure 1. Airborne sound transmission paths

- The reduction of transmission of airborne sound between the source room and the receiving room is the so-called airborne sound insulation.
- Concerning the structure borne sound, which is caused by people walking, sliding of chairs, dropping of objects, etc., i.e., the sound energy that reaches the receiving room due to an impact hit. In the same way, the reduction of the radiation process in the receiving room, related to impact sound, is called the impact sound insulation.

Acoustic Performance

- In order to get a good acoustic performance, three fundamental aspects should be considered at the design stage:
    - Type of construction (single leaf, double leaf, etc.);
    - Mass per unit of area of the partition, internal losses, existence (or not) of absorption material partially filling the air cavities;
    - Air tightness and sealing.

  Flanking transmission

  The flanking transmission is determined by the type of element and edge conditions. If there is a high flanking transmission the sound insulation between two adjacent rooms can be much lower than expected.

  Regarding airborne sound, the flanking transmission can only be negligible in the case of façades, for its sound insulation is very poor when compared with that of the flanking elements.

  In the case of impact sound, to minimize the flanking transmission a floating floor self-contained within each room should be used. Each partition should neither be built on top of the floating floor nor reach the ceiling where a special sealing treatment must be used. Regarding movable partitions, floating floors should be separated by joints at all possible positions.

  Impact sound

  Concerning the impact sound insulation and in order to get a good acoustic performance some fundamental aspects should be taken into consideration:
    - the use of resilient layers separating the floor beneath the partitions;
    - the use of floating floors which should be cut off beneath the partitions;
    - the use of resilient floor coverings;
    - the use of suspended ceilings made of boards with small stiffness.

  Massive walls

  Massive walls, as brick or concrete block masonry walls, are not usually used in MBT buildings because they are very heavy. The sound insulation of this type of partitions is almost entirely influenced by their mass per unit area. Other factors with less influence are the loss factor, the stiffness, and the bending conditions. In the case of the use of these types of walls in a steel construction it's important to insulate the steel profiles from the walls and enclose them with a resilient separating lining in order to avoid the vibration propagation to the steel structure.

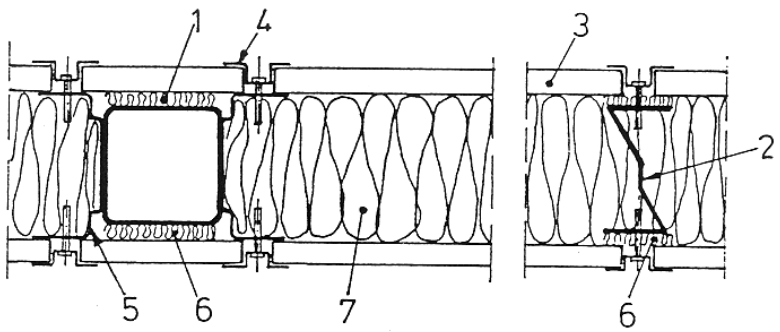
  Lightweight board walls

  Lightweight board walls are the most commonly used solutions to make partitions and separating walls in MBT buildings. This type of walls can be made with a single frame or a double frame supporting single leaf or double leaf boards.

  For lightweight board walls, normally, less mass is required to achieve the same sound insulation as in the case of massive walls. But the elastic characteristics of the board leafs has to be carefully chosen in order to locate the coincidence frequency below the

100 Hz frequency band.

The sound insulation of lightweight board walls is not influenced by the steel supporting frames provided the boards are effectively separated from the construction as shown in Figure 2 (Cremer, 1973).



1 – 50 x 60 mm steel support
2 – Z-shaped steel sheet support
3 – 13.5 gypsum board with plastic coating
4 – Omega profile and rubber profile
5 – Metal sheet profile
6 – Intermediate layer of foamed plastic strips
7 – 73 mm mineral wood matting

Figure 2. Cross section of a lightweight double leaf wall

A new separating wall type comprising steel studs and sheathing boards has been developed in co-operation between Rautaruukki Ltd and VTT (Salmi, 2002). The work has resulted to a single-leaf wall with so called acoustic steel studs RAN AWS-studs (see Figure 3). Compared to traditional double-framed wall systems, the use of the new RAN AWS wall system brings significant benefits in constructability and economics. Erection of single stud system is swift and efficient because of the amount of studs reduced to a half and simplified installing of insulation.

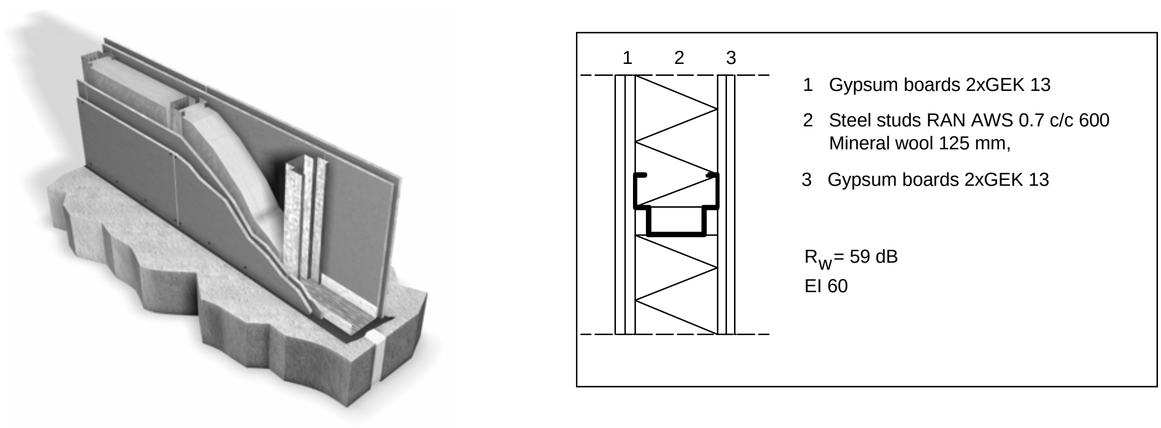


Figure 3. The new RAN AWS lightweight separating wall for load bearing and non-load bearing applications (Salmi, 2002)

<u>Massive floors</u>

For this type of bare floors, good impact sound insulation is not an easy task. Normally, to accomplish national regulations the use of acoustically efficient floor coverings is a basic need. Besides, the influence of flanking transmission is not negligible. Notwithstanding, a good impact sound insulation can only be achieved by using a resilient floor finish.

<u>Double leaf floors</u>

This type of floors can be used in lightweight constructions. However, they must be designed with care in order to minimize flanking transmission as well as good air tightness (Josse, 1977). To ensure good impact sound insulation a resilient floor finish can do the job.

Building's Acoustic Performance Assessment

- Due to the inaccuracy of the existing numerical estimation methods (Bragança, 2001), the only effective way to evaluate building's acoustic performance is by measuring each building partition noise insulation.
- In order to measure the airborne sound insulation between rooms a sound source is placed inside the emission room. The sound pressure levels in the source room (Figure 4) and in the receiving room (Figure 5) are measured on a 1/3-octave band. The sound pressure levels should be spatially averaged.

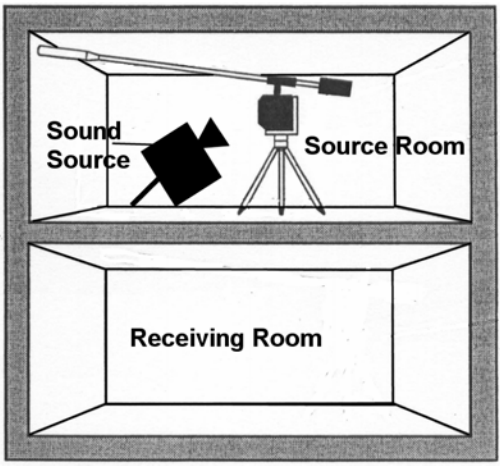


Figure 4. Sound pressure level in the source room

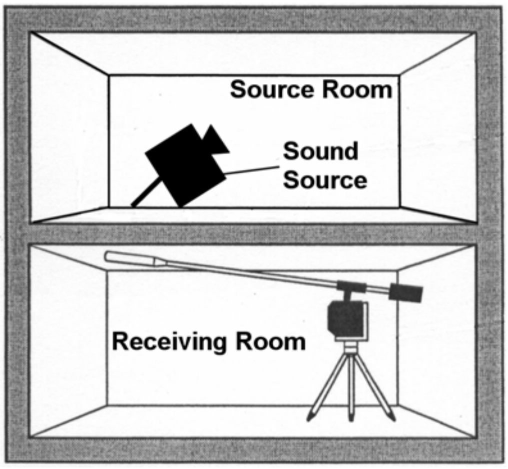


Figure 5. Sound pressure level in the receiv. room

- <u>Sound insulation of façade elements and façades</u>

  A method to evaluate the sound insulation of façade elements, $D_{2m,n}$, considers a loudspeaker as the sound source and the measurement of sound pressure levels at a distance from the façade equal to 2 m, and inside the reception room on the assumption that the sound field is diffuse. The $D_{2m,n}$ is given by the following equation:

$$D_{2m,n} = L_{1,2m} - L_2 + 10\log\left(\frac{A}{A_0}\right) \text{ dB} \quad (1)$$

Where:

$L_{1,2\text{ m}}$ - is the average sound pressure level on the surface of the façade, measured at 2 m distance from the façade;

L_2 - is the average sound pressure level in the receiving room;

A - is the equivalent sound absorption area of the element;

A_0 - is the reference equivalent sound absorption area in the receiving room.

- <u>Airborne sound insulation between rooms</u>

  The recommended method to evaluate the sound insulation of building partitions between rooms, D_n, on the assumption that the sound field in both rooms is diffuse. D_n is given by the following equation:

$$D_n = L_1 - L_2 + 10\log\left(\frac{A}{A_0}\right)dB \qquad (2)$$

Where:

L_1 - is the average sound pressure level in the source room;

L_2 - is the average sound pressure level in the receiving room;

A - is the equivalent sound absorption area of the receiving room;

A_0 - is the reference equivalent sound absorption (equal to 10 m^2).

- Impact sound insulation of floors

  To measure the impact sound insulation of floors a standardised tapping machine should be used in order to exert a standard impact in the source room floor. Then the sound pressure levels in the receiving room on a 1/3-octave band should be measured (Figure 6). The sound pressure levels should be also spatially averaged.

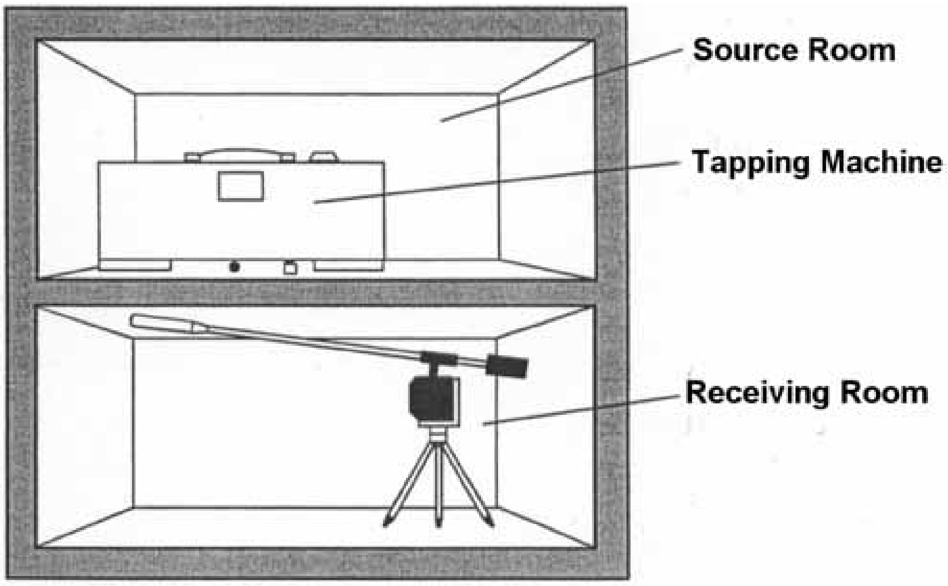


Figure 6. Measure of the impact sound insulation

The recommended method to evaluate the impact sound insulation of floors considers the normalized impact sound pressure level, L'_n, which is given by the following equation:

$$\boldsymbol{L'_n = L_2 - 10\log\left(\frac{A}{A_0}\right)} \qquad (3)$$

Where:

L_2 - is the average sound pressure level in the receiving room;

A - is the equivalent sound absorption area of the receiving room;

A_0 - is the reference equivalent sound absorption (equal to 10 m^2).

- The last step is the fitting of a standard reference curve to the measured sound reduction/transmission curve (D_n and L'_n). The resulting values are the weighted sound reduction index ($D_{n,w}$) and weighted normalized impact sound pressure level index ($L'_{n,w}$).

Guidelines and/or codification

- NP EN ISO 140-4: 2000. Acoustics - *Measurement of sound insulation in buildings and of building elements - Part 4: Field measurements of airborne sound insulation between rooms.*
- NP EN ISO 140-5: 2000. Acoustics - *Measurement of sound insulation in buildings and of building elements - Part 5: Field measurements of airborne sound insulation of façade elements and façades.*
- ISO 140-7: 1998. Acoustics - *Measurement of sound insulation in buildings and of building elements - Part 7: Field measurements of impact sound insulation of floors.*
- EN ISO 717-1:1996. Acoustics - *Rating of sound insulation in buildings and of building elements - Part 1: Airborne sound insulation.*
- EN ISO 717-2: 1996. Acoustics - *Rating of sound insulation in buildings and of building elements - Part 2: Impact sound insulation.*

Example of application: The acoustic performance of a MBT building

- <u>Building description</u>

  MBT buildings combine different structural construction methods in one building. The majority of materials used in this solution are lightweight. Only for structural or energy (e.g. thermal storage) proposes are used heavyweight materials.

  In order to show the acoustic performance of a MBT solution it was selected an office building belonging to the Portuguese Electricity Company (EDP), located in Coimbra - Portugal.

  The building analysed (Figure 7) was rehabilitated using a MBT strategy only in the last floor whilst the first two floors kept the original conventional construction characteristics.
  The internal layout of the MBT floor (Figure 8) is an open space.

Figure 7. Front and lateral view of the building

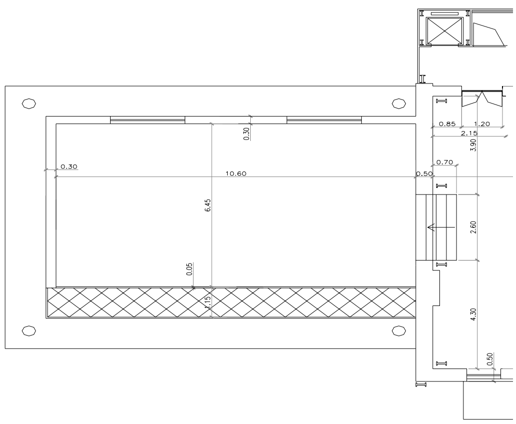


Figure 8. Schematic plan of the MBT building

- <u>Acoustic Evaluation</u>

  Numerous “in situ” measurements where made in order to characterize the sound reduction index of façade ($D_{2\ m,n}$), the weighted sound insulation of building partitions between rooms ($D_{n,w}$) and the weighted impact sound insulation of floors ($L'_{n,w}$).

  These experimental values were compared with the values experimentally obtained in the conventional part of the building with the same geometry in order to better show the acoustic performance of the MBT solutions. Table 1 summarizes the results of the acoustic evaluation.

Table 1 - Buildings acoustic performance

Element type	$D_{n,w}$	$L'_{n,w}$	$D_{2\ m,n}$
MBT Solution	Measured		
South façade (90% glass + 10% opaque)	-	-	30
East/West façade (0% glass + 100% opaque)	-	-	50
North façade (19% glass + 81% opaque)	-	-	40
Floor	53	70	-
Conventional Solution	Experimental Database		
South façade (26% glass + 74% opaque)	-	-	33
East/West façade (9% glass + 91% opaque)	-	-	35
North façade (19% glass + 81% opaque)	-	-	34
Floor	48	77	-

- <u>Comments</u>

  Analyzing the results obtained in the acoustic evaluation of the MBT building it is possible to conclude that in almost all cases the MBT solution has a better acoustic performance than the conventional building, in spite of having less mass. This fact can be explained by the better quality of the glazing and the higher level of insulation of the exterior wall. One of the few cases where the MBT solution has a worst acoustic performance is in the south façade. Such is due to the large area of fenestration of the MBT solution.

  The reason for the better airborne sound insulation of the MBT building floor lies in the floor finishing and in the suspended ceiling used, which with small stiffness and backed with mineral wool quilts, in spite of the higher mass of the conventional building floor, provide this performance.

  The same reason can be pointed out to explain the better impact sound insulation of the MBT building floors. Although the conventional building floor has a higher mass, in the MBT floor, the air gap and the mineral wool quilts between the slab finishing and the suspended ceiling, increases the airborne sound insulation and reduces the impact sound pressure level.

References

- Bragança, L.; Patrício, J. 2004. Case study: Comparison between the acoustic performance of a Mixed Building Technology building and a conventional building. Building Acoustics, Volume 11, London, “Accepted and to be published in N.º 3, June, 2004”.

- Bragança, L. et al. 2001. Acoustical Performance of Lightweight and MBT Buildings. Working Paper presented in the WG3-Urban Design meeting, Bled, Slovenia, 16-17 September, 2001.
- Cremer, L. and Heckl, M.1973. Structure-borne sound: structural vibrations and sound radiation at audio frequencies. Berlin, Springer-Verlag.
- Salmi, P. et al. 2002. New AWS steel stud for partition walls. International Iron and Steel Institute World Conference IISI. Luxembourg 15-17 May 2002 Steel in sustainable construction. International Iron and Steel Institute. Brussels, p. 197 - 202.
- Josse, R. 1977. A l’usage des architectes ingénieurs urbanistes. Éditions Eyrolles, Paris.
- Meisser, M. 1978. La Pratique de L’Acoustique dans le Batiment. Éditions Eyrolles, Paris.
- Patrício J. 2004. Acústica nos edifícios (Acoustics in buildings) Author’s Edition, Lisbon.
- Patrício, J.; Bragança, L. 2004. Some Considerations about the Contribution of Roller Shutters Positions to Noise Insulation of Façades. Submitted to Building Acoustics Journal, in March, 2004 (situation: under revision).

Contacts

- Prof. Luís Bragança

  Address: Department of Civil Engineering, University of Minho, Azurém, Guimarães, Portugal.
  e-mail: braganca@civil.uminho.pt
  Phone: +351 253 510 200, Fax: +351 253 510 217

- Dr. Jorge Patrício

  Address: National Laboratory for Civil Engineer, Av. Do Brasil, 101, 1700-066 Lisboa, Portugal.
  e-mail: jpatricio@lnec.pt
  Phone: +351 218 443 273, Fax: +351 218 443 028