An Experimental Approach to the Evaluation of Acoustic Behaviour of Beam and Clay Block Floors

Antonino Di Bella
DFT - Department of Technical Physics, University of Padova, Padua, Italy.

Alessandro Schiavi
INRIM - National Institute of Metrological Research, Turin, Italy.

Giovanni Semprini
DIENCA - Department of Energy, Nuclear and Environmental Protection Engineering, University of Bologna, Bologna, Italy.

Arianna Astolfi
DENER - Department of Energetics, Polytechnic University of Torino, Turin, Italy.

Summary

The estimation of acoustical performance of horizontal partitions from the performance of elements and components using EN 12354 Standard do not actually provides satisfactory results when applied to beam and clay block floors.

Over the last years many comparisons between in situ measurements and empirical estimations have been made, and the results show indisputably great differences between the results obtained through estimation models and the measured data for this type of floors.

In this work an experimental approach to this problem is presented and a reference curve of impact sound pressure level for beam and block floors made by hollow clay blocks is proposed in order to provide representative field values for resilient flooring starting from the reduction of impact sound pressure level measured in the laboratory on a homogeneous isotropic concrete slab floor.

PACS no. 43.40.Kd, 43.55.Ti

1. Introduction

Different independent research groups are working in Italy in the building acoustics field in order to improve the accuracy of the estimation of impact noise for floors types widely diffused in European building construction, but not well represented by standardized prediction models.

Starting from the assumption that the reduction of impact sound pressure level is independent from the base floor, an extensive program of in-situ measurements on beam and clay block unfinished floors has been implemented in the last years. Afterwards, a comparison between the results of the same structures with a floating floors and the predicted values was made. From these studies, a parametric model for beam and clay block floors was proposed and currently the researchers involved in the project are working to improve the correlation of the model by the increase of data collected in situ on unfinished floors.

2. Building technology of beam and clay block floors

In general the beam and clay block floors are consisting of structural elements of reinforced concrete (beams) and elements of brick with cavities or hollow blocks.

The floor is usually completed with a concrete screed on the top surface of the components, with the aim to connect the different elements and to distribute the load between the ribs.

This flooring structural system, widespread in Southern European countries as well as in South America mainly for residential buildings, has many advantages compared to other horizontal structures.

In particular, it is very versatile from construction point of view to allow the execution of complex architectural shapes and the articulation of spaces and connections between different parts of the building. Among the plans bearing surface, this structure represents the best compromise between weight and load capacity in the same walking surface, also it has good thermal and acoustic performance at low frequencies and it is easy to assemble and cast-in-place, also without a crane.

The design, construction and testing of beam and clay block floors is regulated by different rules, orders and ministerial decrees.

Regarding the characteristics of hollow brick and concrete floors, the EN 15037-3 Standard [1], states the requirements and performance of the blocks of hollow brick, used in conjunction with concrete beams with or without concrete screed for the construction of floors and roof joist systems and blocks.

In Figure 1 the most common types of floors characterized by different modes of realization of horizontal structures are shown. There are floors to be built on building site, requiring a continuous support structure, floor joists in concrete block and brick floors and prefabricated panels or plates with light brick.

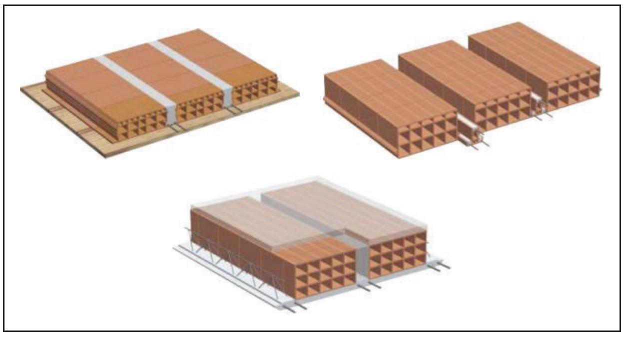

Figure 1. Examples of typical beam and clay block floors.

3. Acoustic behaviour of beam and clay block floors

The acoustics radiation of complex building structures, such as clay brick and concrete slab is not correctly evaluable using common prediction models such as SEA or simplified calculations stated in EN 12354 Standards. The main reasons, as recently demonstrated by Brunskog et al. [2], are due to the non-diffusivity of the vibrational field, to the presence of structural discontinuities of the orthotropic systems, to the complexity of the modal density due to the periodicity of the structure, and to the sound radiation of an irregular field such as a plate composed by two different typology of materials (such as concrete plate and hollow brick “beams”). A bare beam and block floor can be considered as a rigid plate with concrete ribs (ribbed plate) rigidly coupled to hollow bricks, that cooperate in the distribution of the static load.

The acoustical response to impact excitation of this kind of floors, due to resonances and high radiation efficiency of brick elements, especially at high frequencies, differs considerably from the trend of the spectrum of a monolithic and homogeneous concrete slab.

4. Experimental analysis of bare beam and block floor

In recent years, several independent Italian researchers have made field measurements of impact sound pressure level on bare floors.

A specific measurement procedure has been developed, that requires the creation of special square areas of about 0.6 m² on the structural concrete screed for tapping machine arrangement.

The square areas are finished with hard self-levelling cement or with a mixture of liquid cement and quartz-sand, in order to obtain a very thin and smooth surface close-fitting to the floor structure (Figure 2).

Figure 2. Example of bare floor slab finishing for tapping machine arrangement.

From test procedure and evaluation point of view, the measurement procedure fulfil requirements of the ISO 140-7 Standard [3]. At least four different positions of the tapping machine on the floor under test were used, with the hammer connecting line oriented at 45° to the direction of the beams. In many cases, the measure was repeated for each

(c) European Acoustics Association, ISBN: 978-84-694-1520-7, ISSN: 221-3767

point with the 90° rotation of the tapping machine (Figure 3).
A thorough inspection of the flanking transmission was performed and the openings in the measuring rooms were closed with wooden panels and mineral wool (Figure 4).
Nowadays, over 50 bare beam and clay brick floors were measured following this procedure and the results are shown in Figure 5.

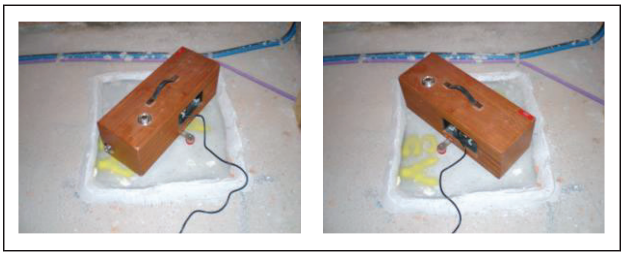

Figure 3. Example of tapping machine positioning with opposite orientation of the hammer connecting line for the same measurement point.

Figure 4. Example of installation of a temporary door. The sound absorbing side of the panel is placed outside the measuring room.

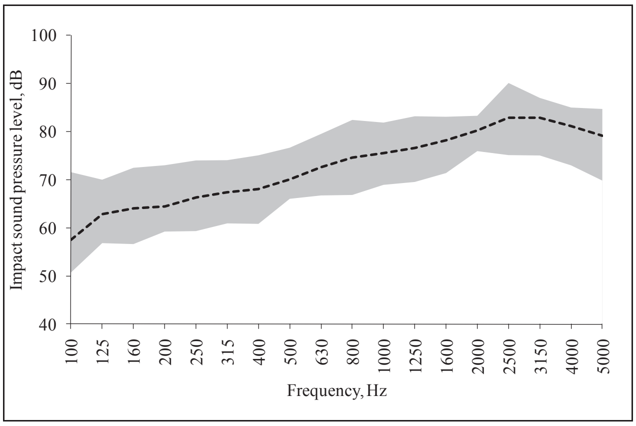

Figure 5. Distribution of field measurements of the impact sound pressure level for various beam and clay block bare floors (grey area). The average value is highlighted (dotted line). The average standard deviation is about 4 dB.

5. Proposal of a reference curve of impact sound pressure level for beam and block floors

Based on available experimental data, a reference spectrum of the impact sound pressure level of bare beam and clay brick floors ($L'_{n,bf}$) was proposed [4, 5 and 6], as shown in Figure 6.

Freq., Hz	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
$L'_{n,bf}$, dB	59.5	61.0	62.7	64.2	65.8	67.3	69.0	70.5	72.1	73.7	75.2	76.8	78.5	80.0	81.5	81.7	78.6	75.8

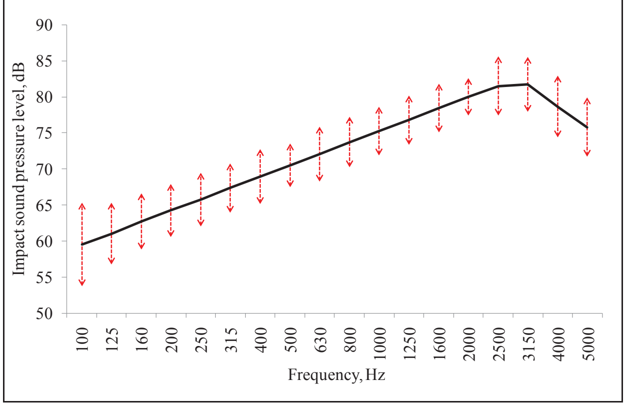

Figure 6. Reference curve of impact sound pressure level of bare beam and clay brick floors ($L'_{n,bf}$). The standard deviation is highlighted (red arrows) and the numerical values are also reported.

The curve $L'_{n,bf}$ can be used to provide a qualitatively evaluation of the impact sound pressure level of a floating floor, built on a beam and clay brick base floor. In order to calculate the impact sound pressure level L'_n it is anyway necessary to have the frequency spectrum of the reduction of impact sound pressure level data, ΔL, measured in laboratory according to ISO 10140 Standard part 1 and 3 [7, 8]; or, at least, ΔL data may be estimated from dynamic stiffness of the resilient material used as underlayer in the floating floor, according to the calculation model proposed in literature and collected in EN 12354-2 Standard [9].
The impact sound pressure level L'_n of a floating floor built on a beam and clay brick base floor, can be estimated with good reliability, according to the following relation:

$$L_n^{'} \approx L_{n,bf}^{'} - \Delta L + 15 \log \frac{m_{lab}^{'}}{m_{situ}^{'}} + \Xi \qquad (1)$$

where:

- $L'_{n,bf}$ is the "reference standard beam and clay brick base floor" value as a function of frequency are reported in Figure 6, in dB;
- ΔL is the reduction of impact sound pressure level measured in the laboratory according to ISO 10140 Standards, expressed as a function of frequency, in dB;
- m'_{lab} is the mass per unit area of the floating slab in the laboratory, in kg/m²;
- m'_{situ} is the mass per unit area of the floating slab in situ, in kg/m²;
- Ξ is a general corrective term, frequency depending, which takes into account the increase of the sound pressure level due to the flanking transmission. If in the receiving room, where L'_n must be determined, there are at least two junctions of the type bricks-bricks between floor and walls, the value Ξ = 2 dB is suggested; in all other cases must be considered, conservatively, Ξ = 0 dB.

6. Improvement of the prediction model for impact sound pressure level for beam and block floors

At present the available experimental data concerning about 50 floors and dispersion of the data has a standard deviation of about 4 dB on average. Many results of previous measurements have been correlated to in situ evaluation of the flanking transmission.
In order to improve the reliability of the proposed prediction model for beam and block floors, a web site was created with the aim to spread the knowledge about the measurement procedure used for this study and to collect new data [10].
The collected data are regularly updated and can be freely accessed. It is possible to upload new data carried out according to the described measurement procedure and that comply specific rules about the description of the floor and the flanking construction.
The increase of available data can be useful to improve the accuracy of the method, which could be used to optimize the characteristics of the floating floor systems for this type of structure.

7. Conclusions

In this work was presented the measurement procedure that has allowed to propose a prediction model of the acoustical behaviour of beam and clay brick bare floors.
The dispersion of the data currently available can therefore be considered satisfactory, taking into account the difficult conditions of field measurement, on unfinished floors and without windows or doors. But it is also important to point out that the collected experimental data have been measured independently by four different research teams with different measurement systems and instrumentations in various construction sites.
Acoustic and vibrational measurements performed on construction sites, during specific build up phases, can be extremely useful in improving the knowledge of the acoustical behaviour of building structures, especially for the floors.

Acknowledgement

This work was inspired by Ermenegildo Brosio researches on building acoustic.

References

[1] European Standard EN 15037-3: Precast concrete products - Beam-and-block floor systems - Part 3: Clay blocks, 2009.

[2] J. Brunskog, K. Dickow, M. Ohlrich: Modal density and modal distribution in a ribbed plate. Proc of InterNoise 2009.

[3] International Standard ISO 140-7: Acoustics - Measurement of sound insulation in buildings and of building elements - Part 7: Field measurements of impact sound insulation of floors, 1998.

[4] A. Schiavi et al.: Proposal for a Reference Floor for Hollow Brick and Concrete Slabs Based on Italian Experiences. Proc. 20th Int. Congr. on Acoustics ICA 2010.

[5] G. Semprini et. al.: Acoustical Behaviour of Bare Floor in Hollow Brick and Concrete (Italian Building Technology). Proc. InterNoise 2010.

[6] A. Di Bella et al.: Il comportamento acustico dei solai laterocementizi. Proc. 37th Congr. of Acoustical Society of Italy AIA 2010 (in italian).

[7] International Standard ISO 10140-1: Acoustics - Laboratory measurement of sound insulation of building elements - Part 1: Application rules for specific products, 2010

[8] International Standard ISO 10140-3: Acoustics - Laboratory measurement of sound insulation of building elements - Part 3: Measurement of impact sound insulation, 2010

[9] European Standard EN 12354-2: Building acoustics - Estimation of acoustic performance of buildings from the performance of elements - Impact sound insulation between rooms, 2000

[10] Acoustic Behaviour of Beam and Clay Block Floors (Research Group Web Pages): https://sites.google.com/site/acousticbeamandclayblockfloors/