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Sound insulation of building elements at low frequency: a modal approach

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Abstract

In typical laboratory volumes (50-80 m^3) and at low frequencies (50-100 Hz), the acoustic field is non-diffuse due to the presence of source and receiving room modes. Under such conditions, standard sound insulation measurements and descriptors are not adequate to correctly characterize the insulating property of partitions or flooring systems. The «modal approach» allows to evaluate the airborne sound insulation by the determination of modal transmission loss, or modal sound insulation, of a single mode passing through the partition. Proper normalization terms and an extension method to one-third octave bands are also introduced. The same approach is applied to impact sound insulation measurement.

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Keywords: Airborne sound insulation; Building acoustics; Low frequency; Impact sound insulation; Laboratory measurements.

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1. Introduction

In recent years an increasing interest in building acoustics measurements at low frequencies (i.e. below 100 Hz, and typically from 50 Hz) has been observed. The consideration of low frequency noise has become more and more important because of the increasing occurrence of sound sources with low frequency content, like technical equipment inside and outside buildings, increased traffic volume and improved video and audio equipment in dwellings, and renewable energy sources [1,2]. Simultaneously, newer multilayer building elements, developed to be cheaper and lighter and possibly to have a better thermal insulation, use to have resonant frequencies below 100 Hz, which become more and more disturbing under such circumstances. Nevertheless, at present time, effective protection systems against low frequency noise are still an open challenge both for researchers and components

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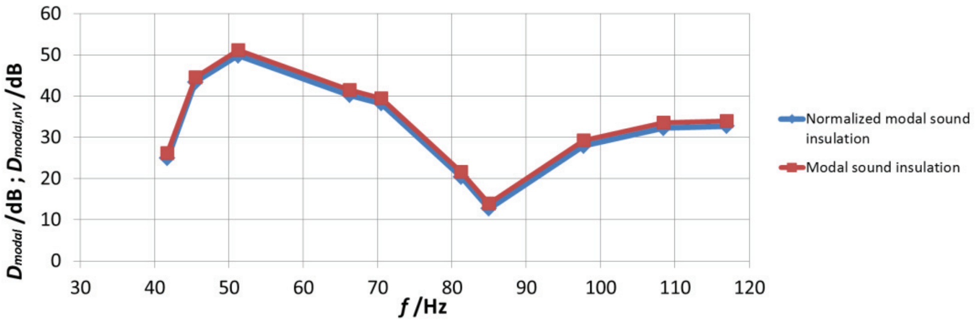

Fig. 2. The modal sound insulation curve.

2.3. Extension to the whole low frequency range

Because of the discrete nature of modal sound insulation, a new method is also introduced in order to extend it to the whole low frequency range in one-third octave bands. Considering a laboratory room with different volume and dimensions, it is possible to assume that resonant frequencies can shift in frequency and move along the envelope of source and receiving room spectra, i.e. along the curve that connects resonance peaks [11]. In this way, modal sound insulation (both for D_{modal} and $D_{modal,nV}$) is extendible to the whole 44-112 Hz range and one-third octave band representation is possible (Fig. 3).

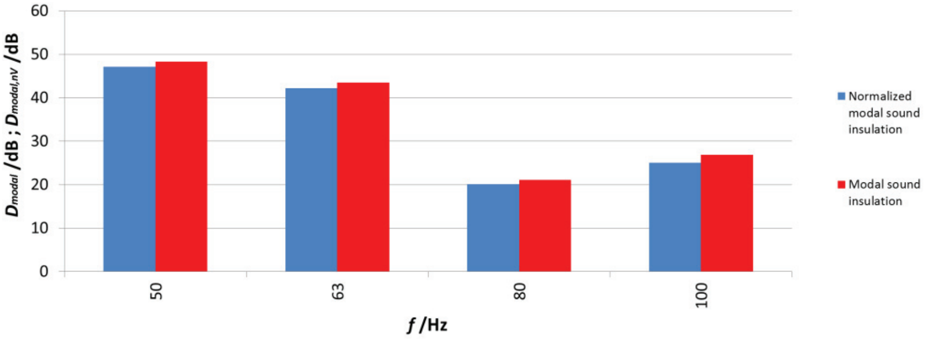

Fig. 3. The modal sound insulation in one-third octave bands.

3. The modal approach for impact sound insulation

3.1. The modal impact sound pressure level and the improvement of modal impact sound insulation

As for airborne sound insulation, also existing impact sound insulation indexes described in ISO 10140-3:2010 need to be reviewed and adapted in order to best describe the physical phenomenon in connection with the actual auditory perception of noise due to modal field and to ensure repeatable and reproducible laboratory values. Different authors have modelled the effect of the impact sound transmission by using low frequency modal analysis and provided a good prediction of the acoustic field generated in a rectangular room with a punctual sound source [12]. Based on these results and on the modal approach introduced for airborne sound insulation, it is proposed to move from a statistical approach typical of diffuse field to a discrete one, focused on the points of highest noise and annoyance, i.e. the highest sound pressure levels in the space (corners) and frequency (resonance modes). For this purpose, two descriptors are introduced: the modal impact sound pressure level, $L_{modal}(f_n) = L_{p,max}(f_n)$, defined as the highest sound pressure level measured at corners of receiving room for each resonance frequency, f_n, and the improvement of modal impact sound insulation, φL_{modal} (f_n), defined as the difference between the highest sound pressure levels measured with the bare floor and the covered floor:

$$\varDelta L_{modal}(f_n) \mid L_{modal,0}(f_n) - L_{modal}(f_n) \tag{3}$$

where $L_{modal,0}$ (f_n) is the highest modal sound pressure level measured with the bare slab and L_{modal} (f_n) is the highest modal sound pressure level measured in receiving room corners with the covered floor. Such descriptor provides an indication of modal sound pressure level reduction due to the floating floor. For mass-spring systems (a rigid covering and the resilient layer), transmissibility curve has a peak around the resonant frequency of the system, f_0. Around the resonant frequency, the transmissibility is greater than 1 and higher sound pressure levels with the floating floor are obtained rather than with the bare slab. For lower frequencies, transmissibility is close to 1, and sound insulation is close to 0 [13].

3.2. Experimental tests

On the base of this, experimental measurements of modal impact sound pressure levels and improvement of modal impact sound insulation are performed with different mass-spring systems. Three floating floor samples, assuming locally reactive approximation, according to their different structural characteristics (mass and resonant frequency measured with dynamic stiffness method, ISO 9052-1:1993) are tested and described in Table 1.

Table 1. Description of test elements.

Name	*Covering material*	*Resilient layer*	*M / kg m^{-2}*	*A / m^2*	*f_0 / Hz*
M1	Carpet	LDPE	7.65	0.1830	511
M2	Concrete	LDPE	89.95	0.0756	149
M3	Steel	LDPE	200	0.04	38

The purpose of such measurement campaign is to verify the new measurement method for the evaluation of the impact sound insulation at low frequency and compare it with the sound transmission theory. In accordance with the definition of the new impact sound insulation descriptors, measurements of modal sound pressure level in the receiving room were performed. The source room floor was mechanically stressed by a heavy/soft ball and the sound field radiated by the floor was measured at the four corners of the receiving room. From the four spectra obtained for each corner, maximum levels for each narrow band were selected in order to obtain the discrete spectrum of $L_{modal}(f_n)$. Modal sound pressure level curves of the three test elements, with bare and covered floor, agree with transmissibility theory. Curves of improvement of modal impact sound insulation are depicted in Fig. 4. The analyzed mass-spring systems, with resonance frequencies between 38 Hz and 511 Hz, do not contribute to the sound insulation in the low frequency range (M1, the curve is, on average, around zero), but, on the contrary, can cause noise amplification (M2 and M3 curves decrease approaching their resonant frequencies).

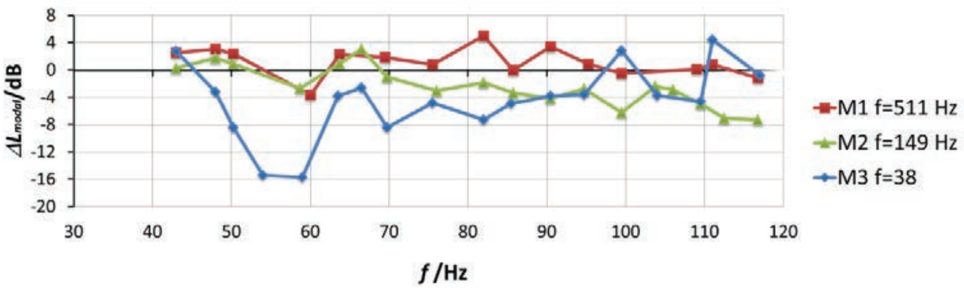

Fig. 4. Improvement of modal sound pressure level for the three mass-spring systems.

In M3 curve, the negative peak is reached at 55 Hz and 65 Hz, instead of 38 Hz. Below 55 Hz, improvement of modal impact sound insulation even increases until the first mode at 43 Hz. This is probably due to the airborne transmission of first modes from the source into the receiving room through the floor. For this reason, in the future it is necessary to evaluate the influence of airborne component in impact sound insulation measurements.

As for modal airborne sound insulation, the application of the envelope method allows a representation in one-third octave bands, as required by ISO Standard, of modal impact sound pressure levels, as well as for the improvement of modal impact sound insulation (Fig. 5).

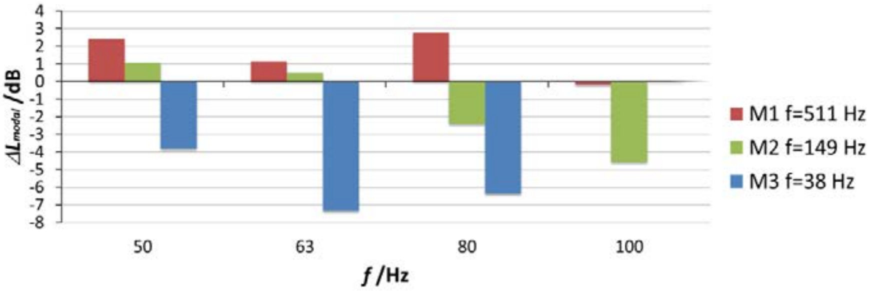

Fig. 5. Improvement of modal sound pressure level in one-third octave bands.

Improvement of modal impact sound insulation presents negative values around their resonant frequency. As most of the common covering floors are characterized by resonance frequencies above 50 Hz, the range of low frequencies presents, in most cases, a null sound insulation, even negative in some cases. Thus, for low frequencies and common flooring systems, it is more useful to control sound amplification rather than sound insulation.

4. Conclusions

The modal approach for the main laboratory measurements of building acoustics (airborne sound insulation and impact sound insulation) at low frequency (50-100 Hz) is introduced and new descriptors are investigated. The preliminary experimental measurements, in accordance with theory, confirm the significance of such indexes. This new approach represents a possible solution for the required extensions of building acoustics measurements down to 50 Hz. Nevertheless, further measurements are necessary in order to validate introduced normalization terms, measurement procedure and to evaluate a weighted procedure to overcome modal match.

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