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Acoustic performances of resilient layers for impact sound insulation in standard laboratory

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Summary

Floor constructions that meet good acoustic requirements are usually built by resilient layers under a concrete floating slab. The impact sound insulation can be evaluated on the basis of EN 12354-2 standard models, in which the values of ΔL or ΔL_W provided by the floating floor can be measured in laboratory on a reference floor or calculated from the dynamic stiffness of the resilient layer: the latter value is obtained from the resonant frequency of the mass spring system by using a specific test rig. In the present work, starting with the experience gained so far by the acoustics laboratory at the University of Bologna and at the Acoustical Laboratories of INRIM in Turin, a comparison of the values of the attenuation level of different resilient materials are presented calculated using the values of dynamic stiffness determined in accordance with the EN 29052 - 1 and those measured experimentally in room acoustics, according to ISO 10140 series requirements. The aim of the authors is to assess the equivalence of the two methods and to compare repeatability and invariability of the dynamic stiffness values with force-load.

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1. Introduction

Acoustical performances of resilient layers used in floating floor systems are evaluated from a direct measurement of the reduction in impact sound pressure level compared to a reference floor using a standard tapping machine (ISO 10140 [1]) or indirectly, by using the theoretical formulation of mass-spring system attenuation [2,3] from the effective dynamic stiffness measured on little sample of the resilient material (EN 29052-1 [4]).

Recent works [5] show good agreement between measured and calculated values of the reduction of impact sound reduction pressure levels for some materials used on concrete floor, but more analysis are required in order to validate the method.

Several typologies of materials have been tested, such extruded polyethylene with closed cells, multilayers extruded polyethylene and EPS with open cells.

In this paper a comparison of calculated and measured acoustical data of impact sound insulation are reported.

2. The measurement of dynamic stiffness

According to EN 29052-1 standard the measurement of dynamic stiffness of materials used under floating floors in dwelling, is evaluated from the resonance frequency f_r of the mass-spring system, where the spring is the specimen of the resilient material (200×200 mm) and the mass m_t' is a loading steel plate with a vertical excitation generated by a shaker.

Figure 1. apparatus for testing the dynamic stiffness

The apparent dynamic stiffness per unit area can be evaluated from the following expression:

$$S'_t = 4\pi^2 m'_t (f_r)^2 \text{ MN/m}^3, \qquad (1)$$

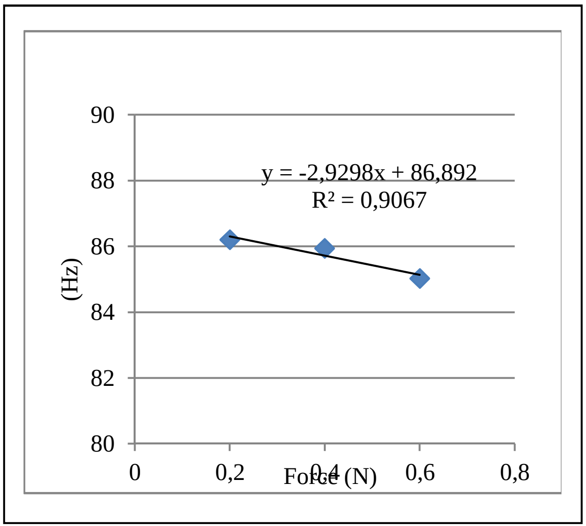

Figure 2. Example of resonance frequency versus excitation force.

For some materials the resonance frequency is force amplitude dependent, so it must be determined by extrapolation to zero force.
According to EN 29052-1, the effective dynamic stiffness s' must be evaluated summing the measured apparent dynamic stiffness s'_t to the dynamic stiffness s'_a of internal gas (air). In Table I results of effective dynamic stiffness are reported, assuming s'_a depending from the thickness *d* (mm) of the material:

$$s'_a = \frac{111}{d} \text{ MN/m}^3 \qquad (2)$$

Table I. Results of apparent and effective dynamic stiffness (MN/m^3).

specimen	s'_t	s'_a	s'
mat 1	63,9	-	63,9
mat 2	57,1	9.3	66.4
mat 3	65,2	15.8	80.0
mat 4	13,8	5	18.8
mat 5	10,2	2.6	14.8

3. Attenuation of impact sound pressure level

The acoustic performance of floating floor over a resilient layer is defined by the improvement in impact sound insulation *ΔL* compared to a base floor. This can be evaluated from laboratory measurements on 10 m^2 of test specimen over a reference concrete floor, or calculated, from the resonance frequency of the mass-spring system (floating floor of mass *m'* and resilient layer with apparent dynamic stiffness *s'*), according to EN 12354-2:

$$f_0 = \frac{1}{2\pi}\sqrt{\frac{s'\,10^6}{m'}} \text{ Hz}, \qquad (3)$$

$$\Delta L = 30 \log \frac{f}{f_0} \text{ dB}, \qquad (4)$$

where f are the center frequency band from 100 to 3150 Hz.
The expression (4) gives an average fixed positive slope of 30 dB/decade, independent from internal damping of resilient material. On the contrary, the actual sound insulation slopes present different behaviors as a function of damping. As shown in a previous research [5], internal damping of resilient materials relevantly influences the sound insulation in laboratory measurements of *ΔL* and calculated values from measured dynamic stiffness, at this moment, does not take into account this behavior.
For each tested materials the mean value of damping coefficient ξ has been evaluated from:

$$\xi = \frac{f_2 - f_1}{2 f_r} \qquad (5)$$

where f_1 and f_2 are the frequency values evaluated a –3dB down (half power decay) from the resonance peak.

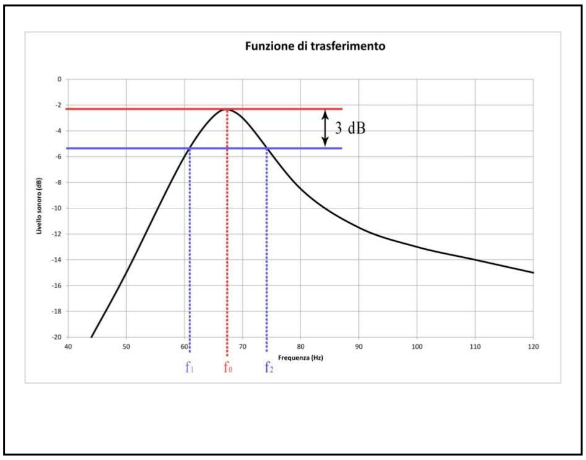

Figure 3. Example of f_1 and f_2 evaluated a – 3dB down (half power decay) from the resonance peak

A modified expression, based on an empirical relation between the actual slope of DL, measured in standard laboratory, and the damping coefficient of the resilient material, a calculated DL, damping dependent [5], can be derived as:

$$\Delta L \approx (37{,}6\text{-}19\xi)\log\frac{f}{f_0} \quad (6)$$

The expression (6) gives a positive slope that depends by damping coefficient ξ.

4. Experimental data analysis

In this paragraph, we compare the values of attenuation in impact noise obtained from laboratory tests on standardized ceiling, with the calculated values according both with formula (4) and modified expression (6)

In Figure 4, the red line describes the performance of *ΔL* according to the measured value in laboratory compliant with the UNI EN ISO 140; the purple line shows the *ΔL* values calculated in according to EN 12354-2; green straight line shows the *ΔL* values calculated with the equation (6).

From the analysis of the graphs of Figure 4, it can be deduced as the values of ΔL calculated using equation (6) of the UNI EN 12354-2, provides a good approximation of the measured values over the entire frequency range (100-3150 Hz).

The improved formula (6) provides the best results with the material 1, where the theoretical curve has an almost perfect overlap with the respective ΔL measured values.

ΔL predicted values (from material 2 to 5) calculated with the improved formula, change the usual slope of 30 dB/octave defined by standards, in a slope of about 36 dB/octave slope, more correlated to experimental data. In order to obtain better correlations, the expression (6) should be further modified.

5. Conclusions

The dynamic stiffness allows to calculate the value of the resonant frequency of the mass-spring system and then checks if the material placed inside the floating floor is suitable to reduce the transmission of impact noise.

It has been observed that the results of attenuation of impact noise, obtained from EN 12354-2, are consistent with data measured in the laboratory (1), by means of a correction factor, ξ.

The damping coefficient introduced in the formula (4) for the calculation of ΔL, allows to obtain a predictive slope strongly comparable to the performance curve of ΔL measured. Since some materials tested can be identified as porous, it is possible, to add the contribution of the dynamic stiffness of the air, relation (2), to provide better prediction of impact sound insulation.

A final consideration can be made on the number of significant digits with which one can express the value of dynamic stiffness. The value associated with a resilient material, calculated in according to the UNI EN ISO 29052 [4], is derived from a series of operations and averages of multiple samples. The use of decimal, whereas the range of s' is included between 4:50 (MN/m^3), is superfluous, so it is much more appropriate to use a classification as proposed in the EN 13163 [6] and in the literature [5].

Acknowledgement

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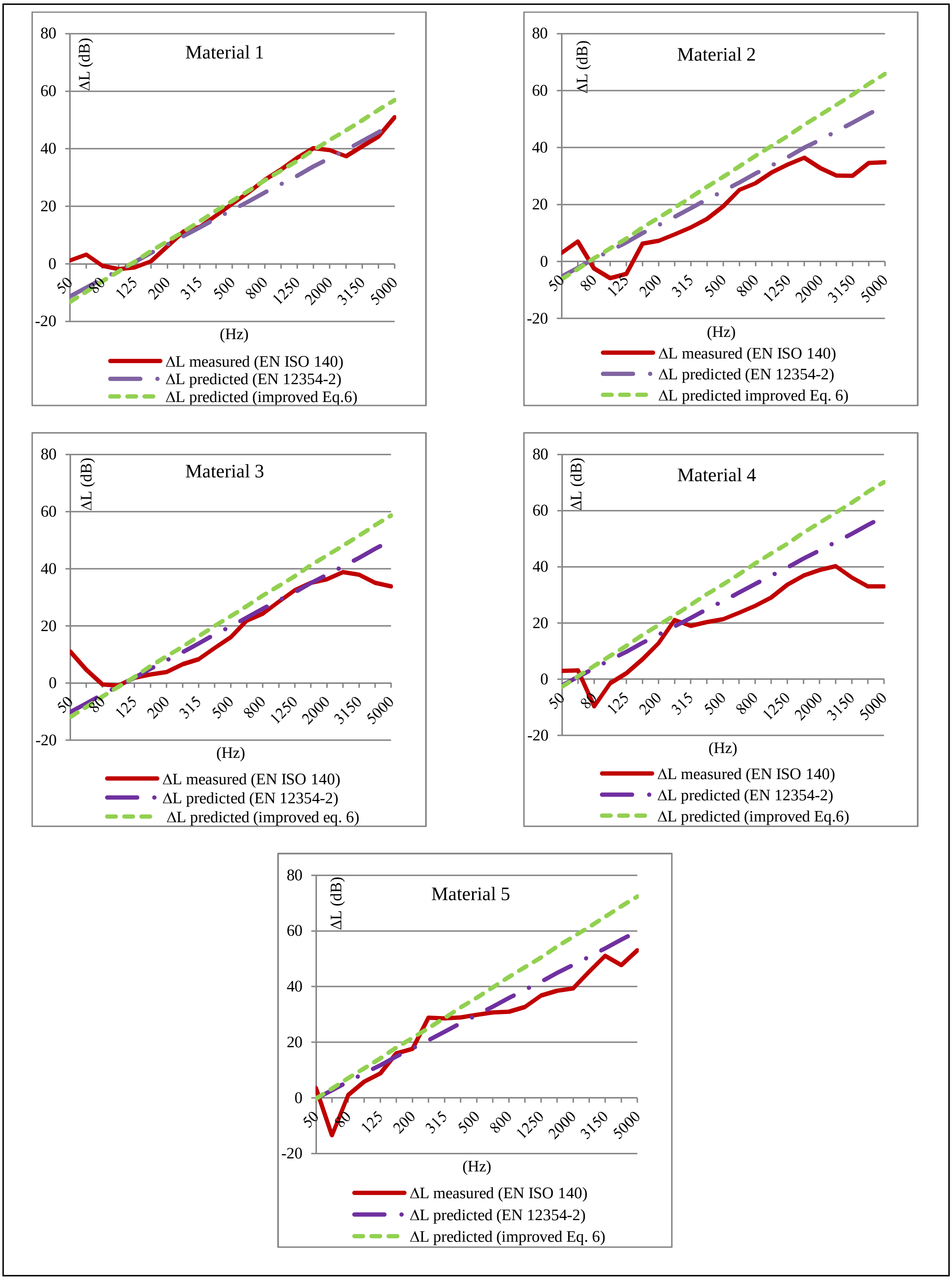

Figure 4. Comparison between the ΔL measured in the laboratory, and the ΔL predicted in according to EN 12354-2 and the improved equation 6