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Sound Power Radiated by Floating Walls: a Review

Max D. C. Magalhaes[1]

[1,]*Professor, Structural Engineering Department, Federal University of Minas Gerais, Belo Horizonte, Brazil*
Corresponding Author: Max D. C. Magalhaes

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ABSTRACT: In this paper, a simplified approach was considered for the investigation of floating wall contribution to the structure-borne noise transmissions in buildings. The wall-floor transmission path was analysed and its effect on the overall sound power radiated into a particular receiving room was calculated using a modal model. The sound power radiated was determined using the Jinc function and measurement values obtained in ref. [7]. Thus, vibration velocity transmitted by a particular floating wall into the receiving room ceiling was computed using proper formulation. It is seen the sound power radiated by floating walls is significantly lower than the one for non-floating walls, as expected.

KEYWORDS: Floating walls, Noise Reduction, Buildings.

I. INTRODUCTION

Recently, various researchers have concentrated their work on presenting the main advantages of floating floors in terms of their sound isolation effectiveness. The use of floating floors on building construction is well-known among civil engineers, architects and acoustic space designers. They are popular not only for their ability to decrease the transmission of structure-borne sound throughout the building structural components but also for their slender dimension which may be relevant on the calculation of the building total cost price.

Although the physical understanding of floating floor mechanisms is well established, the assessment of the sound power radiated by a particular structural floor excited by masonry walls has not been fully considered in terms of theoretical models. Recently most researchers have concentrated their investigation on optimizing the dynamic models of floating floor systems in order to improve their effectiveness, i.e. to minimize the transmitted vibrational energy to the structural floor.

The effects of panel boundaries on sound radiation, including a comparison with an infinite panel have been discussed by several researchers [1-6]. A simple two-dimensional model has been used for evaluating the sound radiation characteristics of finite panels [3]. The analysis of the radiation, through a baffled plate of finite width and infinite length, was conducted rigorously. The effects of panel size have been studied in frequency regions below, above and at the critical frequency. In addition, estimates of averaged response over a given frequency range have also been investigated. The literature survey has revealed that a significant amount of work has concentrated on analysing sound radiation of simply-supported panels.

The use of Jinc functions for the prediction of sound radiated from panels was initially developed and applied to simply-supported panels located in a baffle. Most sound radiation problems require a three-dimensional model for better representation of the sound field distribution. The application of Jinc function description is only appropriate at frequency bands lower than the one that corresponds to propagating bending waves that have a half wavelength larger than the grid spacing of the mesh. The method considers an analytical description of the sound radiation at the panel interface and only requires the normal in-vacuo structural modes. It allows the geometric parameters of the system to be incorporated into the models and subsequent predictions. Subsequently, the frequency response of the system is obtained.

Broadly speaking, the perception of sound radiated from a building floor is greatly influenced by the rooms in which it is immersed and by the position of both listener and source. The main question that remains unanswered is related to the influence of wall-floor connections on the sound power radiated by the structural floor.

Thus, the aim of this paper is to try to answer at least part of this question by investigating the variability of sound radiated from structural

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floor systems subjected to transient input forces as a result of bending waves transmitted through the masonry wall bases. Figure 1 below shows an example of an elastic connection used on floating masonry walls, as a construction technique for structure-borne noise control in buildings.

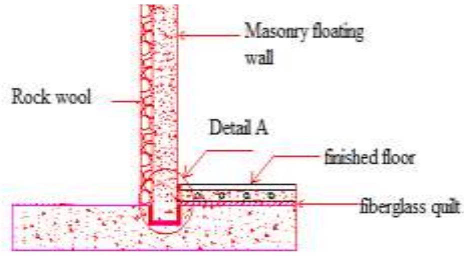

Figure 1. The use of neoprene on the development of floating wall systems in buildings[7].

The novelty of this research corresponds to the application of an alternative method on the building construction scheme for the quantification of the contribution of each interior wall in a source room to the prediction of the structure-borne noise in the receiving room. It can be estimated by the calculation of the total sound power radiated from typical structural-floor systems loaded by rigid or elastic wall-floor connections

II. SOUND POWER RADIATION USING JINC FUNCTIONS

Figure 2. Experimental set-up used for the measurement of the wall transfer mobility [7].a) First configuration: rigid connection between the wall and its support; b) Second configuration: Viscoelastic connection between the wall and its support.

Significant studies have concentrated on analysing vibration transmission using uncoupled 'rigid-walled' acoustic modes for the acoustic volumes [1-9], which could be filled with any type of walls. In this case the boundary condition at the interface between acoustic volumes, which is due to the velocity of the partition, cannot be reproduced. The acoustic waves are those developed inside a room. The acoustic and the structural response fields are typically expressed in terms of their uncoupled normal modes by means of coupled differential equations for each mode. The structural motion is expressed as a summation over the response of the in vacuo natural modes driven by fluid loading. The acoustic fields in the volumes are determined by a summation of the rigid-walled acoustic modes. The correct convergence of the modal pressure on the structural interface is obtained due to Gibb's phenomenon, which is an overshoot that occurs whenever basis functions (for instance acoustic mode shapes) are used to represent spatial distributions containing discontinuities, e.g. in the derivatives of the response. In addition, the optimization of algorithms for the solution of particular numerical problems has been widely used by several researchers [8-10].

The CMS approach [11] was initially developed and applied to acoustic-structural coupled volumes possessing one-dimensionalwave propagation through a limp partition to verify the accuracy and applicability of the approach [11]. Most sound transmission problems require a three-dimensional model for better representation of the sound field distribution. Likewise, the application of the 'limp' mass description is not entirely appropriate in frequency bands higher than the one that includes the fundamental resonance frequency of a partition and so both requirements need to be considered herein.

The modal behaviour of acoustic volumes and structural interface was implemented in just one step where a modified version of the three-dimensional model implemented in ref. [9]. The partition structural modes were incorporated into the acoustic component formulation as 'acoustic constraint modes'. In other words, the modal description for the structural interface (using normal in-vacuo structural modes with the relevant boundary conditions) was incorporated in the source and receiver acoustic components. The component normal modes adopted herein were classified according to their boundary conditions as free-interface modes. The acoustic normal modes adopted are taken to be those of the volumes with a flexible wall at the interface and rigid walls on all other boundaries. The number of normal modes chosen depends upon the frequency range of the calculations and convergence requirements. In order to investigate coupling at low frequencies, structure-borne vibration transmission was measured between a wall and its connected support (along an edge) for two different configurations: with and without a resilient layer (see Figure 2). The wall was made of blockwork, 10 cm thick and 2.8m high with a density of 1400 Kg/m^3 and longitudinal wavespeed of 2300 m/s. A material made from 100 % recycled rubber was laid as continuous strips glued to the topside of the brick support. Its thickness was ¼ ".

The space-averaged mobility amplitude is presented in Figure 3. It is seen that the resonance frequencies are sensitive to the boundary conditions, i.e. the viscoelastic properties of the resilient material (recycled rubber).

The time-average space-average sound power radiated P_{rad} by a plate inserted in an infinite baffle can be computed efficiently using the Jinc function approach [2]. Although this method is not as general as BEM or FEM, it allows much faster analysis of the acoustical power radiated from simple planar structures. The surface displacement of the structure is described using a grid of Jinc function wavelets. The radiated acoustic power can be obtained from the dynamic stiffness of the structure via symmetric wavelets.Thus, the power radiated is then given by

$$P_{rad} = \left(\frac{\omega}{2}\right) \mathbf{a}^{*T}\, \mathrm{Im}\{\mathbf{D}\}\mathbf{a} \qquad (1)$$

where 'D' is the acoustic dynamic stiffness matrix expressed in Jinc function coordinates and 'a' is the amplitude of the jinc function centred at grid point location x_n. It has been shown in reference [2] that equation (5) holds,

$$\mathrm{Im}\{D_{ij}\} = \frac{8\pi\omega\rho_o c_o k_a^2}{k_s^4} \sin c\,(k_a r_{ij}) \quad , \quad \mathbf{a} = \frac{\pi}{2} w(\mathbf{x}_n), \qquad (2)$$

where $r_{ij} = |x_i - x_j|$, $k_s = \sqrt{2}\frac{\pi}{\delta}$, $w(\mathbf{x}_n)$ is the complex amplitude of the panel normal displacement at the grid point $\mathbf{x}_n$, ω is the angular frequency (rad/s), ρ_o is the air density, c_o is the air phase speed, k_a is the acoustic wavenumber, k_s is the structural trace wavenumber of the panel, δ is the size of the mesh spacing (= 8 cm on the calculations) and r_{ij} is the distance between two points, i.e. i and j, on the plate.

This method computes the total power radiated in the near field, by using the air pressure at every point on the plate due to surface displacements. It is assumed that the total power in the near field is necessarily the same as the total power in the far field.

Figure 4 shows an example of the total sound power radiated (Equation 5) by a concrete floor of simply-supported boundary condition. It is seen that the combination masonry wall and resilient quilt is the best one in terms of sound insulation, as total the sound power radiation is less than the one without the resilient material for most of one-third frequency bands. It is seen that the spectrum becomes less pronounced as frequency increases, except at about 300 Hz, where strong fluid-structure interaction occurred due to acoustic and structural mode coupling. The use of viscoelastic strips under walls caused 5-12 dB decrease in the sound power radiated by a simply-supported 80mm concrete slab in the frequency range 50-400 Hz

In practical terms, it might indicate that a more efficient and simpler floating-wall system (probably using only a resilient layer between the floating wall and structural floor) can be designed at higher frequencies.

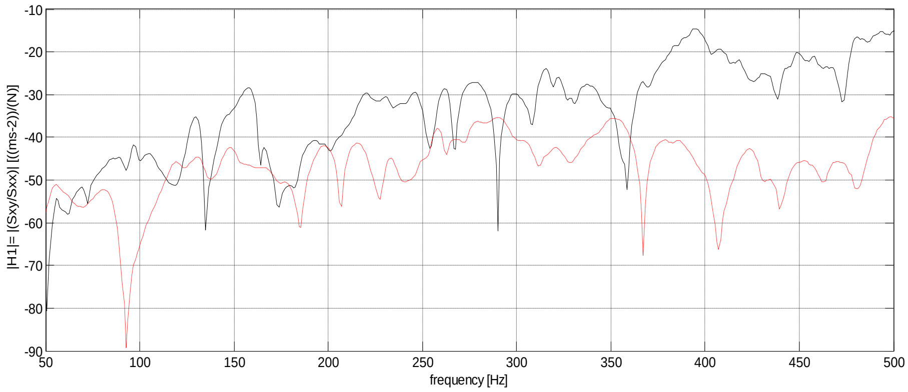

Figure 3. Experimental results for the Frequency Response Function H_1 (Mobility) [7]. ___Black continuous line (Masonry wall +Structural floor); -----Red dashed line (Masonry wall + resilient material + structural floor).

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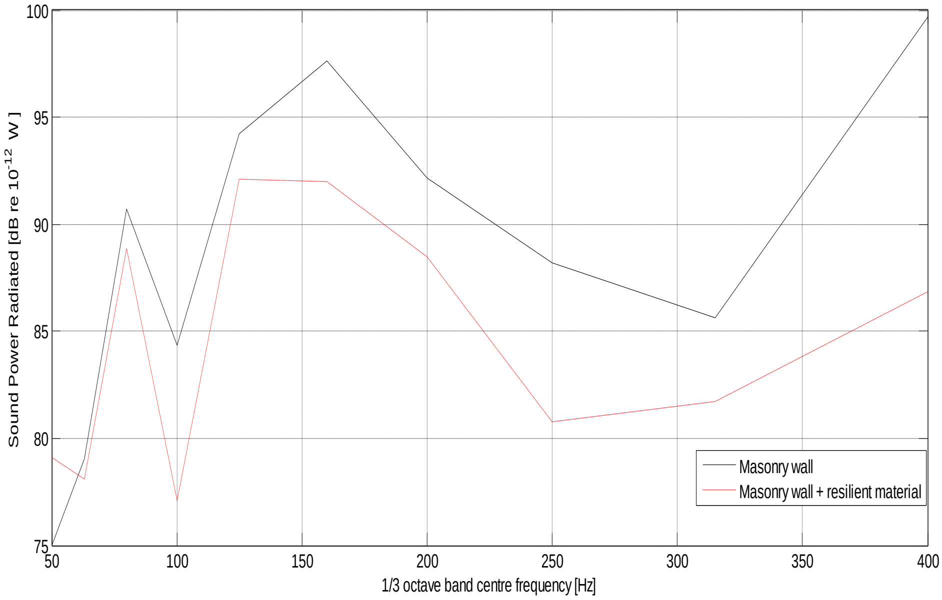

Figure 4. Experimental results for the sound power radiated. ____Black continuous curve (Masonry wall+Structural floor); -----Red dashed line (Masonry wall + resilient material+structural floor

III. CONCLUSION

The experimental study enabled the examination of the effects of the connections between interior walls and their support (structural floor) with respect to the transmitted vibrational energy into a simple-supported concrete slab. This study has also produced sufficient amount of data for the comparison of test and predicted results.

An analytical formulation for the calculation of the sound power radiated was also implemented. A fully coupled model showed the differences between the spectra of the sound power radiated due to floating and non-floating interior walls in a particular source room. The results are strongly influenced by the modal response of the source room. In practical terms, it is assumed that the concrete panel (floor) is driven by the wall in a source room, but radiating into an anechoic receiving room. It is seen that a insertion loss of 5-14 dB can be obtained at low frequency ranges due to the use of a viscoelastic strip under the wall base.

To make the measurement of the transmitted force (at the wall basement) more reliable at low frequencies, the use of an array of forces actuating on the floor and the characterization of other viscoelastic materials can be proposed as future work.

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