THE DYNAMIC RESPONSE OF COMPOSITE FLOATING FLOORS IN BUILDINGS

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1 Introduction

Recently, concerns about sustainability and green technology have been focused on the construction industry. Many buildings are nowadays constructed considering energy saving methods, alternative materials and the use of residues.

Nowadays vegetal fibers are widely used as a substitute to synthetic fibers for acoustics absorption purposes. Vegetal fibers such as the coconut fiber might be considered an alternative option to be used as acoustic materials. The coconut is a natural organic resource which is the seed-hair fiber obtained from the husk (mesocarp) of the coconut. There are many advantages on using vegetal fibers such as those made of coconut. For instance, they are renewable, cheaper and offer no risk to the human health during handling and processing. In the building construction industry most sound absorbing products are based on foams, glass or mineral fiber materials.

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. Thus, various researchers have concentrated their work on presenting the main advantages of recycled materials, such as rubbers, in floating floor systems for sound isolation purposes.

The aim of this paper is to investigate the efficiency of using a combination of coconut fiber and recycled rubber for the vibration isolation of structural slabs in buildings. In section 2, experimental tests were made in order to characterize the coconut fiber boards and rubber in terms of their acoustic impedance (sound absorption) and mobility respectively. In section 3, a modal model was implemented. For this model, the screed and the resilient material are assumed as a one-dimensional mass-spring system lying on a simply-supported elastic floor. In section 4, a Finite Element (FE) model was developed using commercial software. The floating floor system was modeled using laminated (layered) shell elements composed of two different elastic materials, i.e. coconut fiber and recycled rubber. Finally, the conclusions are presented in section 5.

2 Method

Structure-borne vibration transmission was measured between a reinforced concrete plate and its connecter support at low frequencies.

Two different configurations (with and without a resilient layer) were taken into account. The structural plate considered was made of reinforced concrete and simply-supported on its four corners. Its dimensions were 10 cm, 1.2m and 1.16m for the thickness, length and width respectively. The concrete density was 2500 kg/m^3. A rubber quilt made from 100 % recycled rubber (thickness equal to ¼ ”) was glued to the topside of the structural plate. A thinner concrete plate was placed on the resilient material, representing the screed.

The average vibration level of the structural concrete plate was measured when the screed was excited by an impulsive force. The vibration source was a plastic-headed hammer. It was used to hit the floor at different locations (in order to obtain space averaging) over a 5 second measuring duration. The average point mobility of the wall was obtained by measuring the impact force and the acceleration. The velocities were determined from the accelerations using the assumption of harmonic time dependence. The coherence function and the corresponding space-averaged mobility amplitude were measured. 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 results are shown for a narrow frequency band 50-500Hz. It is seen that with the introduction of a resilient quilt the sound insulation was significantly improved. The use of viscoelastic rubber under the screed caused a drastic reduction of at least 20 dB over the whole frequency range 50-500 Hz. The dynamic stiffness per unit area of the specimen was then evaluated.

Figure 1 below shows the modal model considered. It was composed of two connected subsystems: a mass-spring (screed and resilient material) and a plate (concrete slab). The structure subsystem corresponds to the interaction between a floating screed, a resilient quilt and a floor structural plate. For the resilient quilt, two different materials were considered herein: a) recycled rubber and b) coconut fibber.

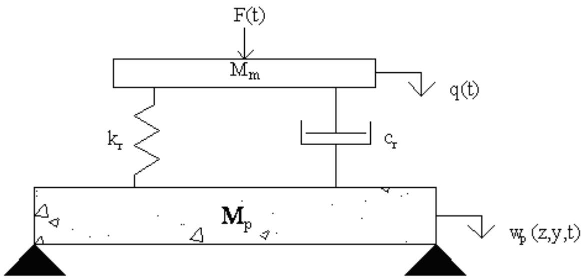

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Figure 1: Floating floor system used in buildings in order to improve the sound insulation properties of the structural floor.

The modal response of the plate w_p (modal displacement) was calculated as:

$$-\omega^2 w_p + j\omega\beta_p w_p + \omega_p^2 w_p = \frac{F_p}{\Lambda_p} \tag{2}$$

$$-\omega^2 q + j\omega\frac{C_r}{M_m} q + \omega_o^2 q = \frac{F_o}{M_m} + \left[\omega_o^2 \phi_p(z_o, y_o) + j\omega\frac{C_r}{M_m}\phi_p(z_o, y_o)\right] w_p \tag{3}$$

$$\begin{aligned} F_p = {} & K_r\left[q\phi_p(z_o, y_o) - w_p\phi_p^2(z_o, y_o)\right] + \\ & j\omega C_r\left[q\phi_p(z_o, y_o) - w_p\phi_p^2(z_o, y_o)\right] \end{aligned} \tag{4}$$

where q is the steady-state amplitude of the mass M_m (screed), β_p is the generalized modal damping coefficient for the structural floor; ω is the excitation frequency in radian/s and F_o .is the force applied on the limp mass M_m. The terms $j\omega\beta_p$ and $j\omega\frac{C_m}{M_m}$ are added on the left-hand side of Eqs. (2) and (3) in order to represent the damping of the flexible structural partition and lump mass. Λ_p is the modal mass of the structural mode p.

3 Results

Figure 2 shows the average mean-square velocity of a simply-supported structural floor subjected to a concentrated load. A point load was applied at the point (z_o, y_o) where z_o =0.3 m, y_o =0.4 m. It is seen that the spatial average mean-square velocity decreased as the frequency increases. The performance of the floating floor system is similar for the use of either rubber or coconut fiber.

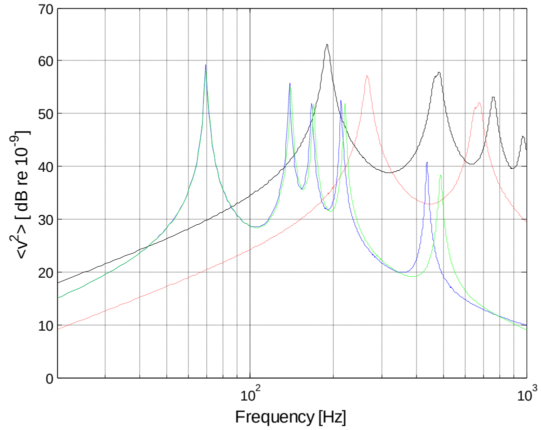

Figure 2: Average mean-square velocity of a simply-supported structural floor. Top black curve (bared structural floor); Middle red curve (floor+screed); Bottom blue curve (floor+rubber + screed); Bottom green curve (floor+coconut fiber + screed)

Figures 3 below shows the layout configuration used on the FE model analysis.

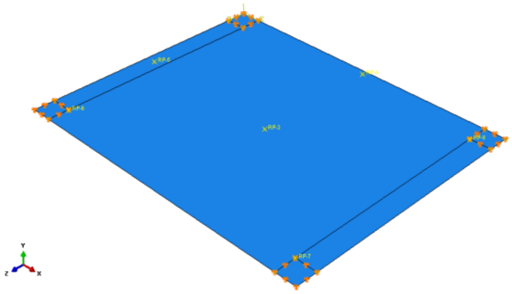

Figure 3: Boundary condition for the floating floor which is supported on its four cornes.

4 Conclusions

The main goal of this paper was to examine the variability of floating-floor efficiency, in terms of its mobility, to different configurations of rubber-coconut layouts. This study was aimed at providing not only a better understanding of the impact transmission mechanism in itself but also to produce a useful set of data which for instance can be used by acousticians as input data for a SEA analysis. This data might be useful for optimizing sound insulation in buildings at low frequencies, where the modal behaviour of rooms strongly influences the transmission.

Although research presents the results for a few resilient material configurations, in principle the same procedure can be applied to any other floating floor system with complex features. As future work, the possibility of using other types of material configuration (e.g. rubber//polymer, rubber//glass fiber, etc) might be another area of investigation. In addition, it will also be very useful to compute the sound radiation pattern.

Acknowledgments

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