ACOUSTIC EFFICIENCY OF FALSE CEILINGS: STUDY ON THE INFLUENCE OF DISTANCE FROM THE CEILING SLAB

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ABSTRACT

Based on the absence of information about the performance of false ceilings, an experimental study regarding the efficiency of continuous false ceilings integrating absorbing material (rockwool) on its hidden surface, placed at different distances from the structural slab was done. The considered distances were respectively 15 cm, 25 cm and 45 cm.

The tests were made both for airborne noise and impact noise. The vibration spectra of the slab and the noise field inside the cavity defined by the false ceiling and the slab were registered. The results obtained led to very interesting and important conclusions.

INTRODUCTION

It is common, in Portugal, the use of continuous false ceilings in housing buildings construction, as an additional decorative element, whose main purpose is normally related to the inclusion of electrical devices, such as modern types of lamps.

It is also currently considered by designers that the acoustic efficiency regarding the increase of noise insulation between apartments - whose horizontal partition is made of a concrete slab with thiknesses in the range of 12 - 17 cm, both for airborne noise and impact noise - provided by these false ceilings are in the range of 3 to 5 dB. The influence of distance (if there´s any) the false ceiling is placed from the slab is always disregarded at the design stage.

Having in mind the absence of information about the performance of these false ceilings, an experimental study regarding the efficiency of continuous false ceilings integrating absorbing material (rockwool) on its hidden (back) surface, placed rigidily at different distances from the structural slab was done. The considered distances were respectively 15 cm, 25 cm and 45 cm.

The tests were made both for airborne noise and impact noise. The vibration spectra of the slab and the noise field inside the cavity defined by the false ceiling and the slab were registered. The results led to very interesting and important conclusions, supporting the consequent progress of the theme in the future.

TEST FACILITIES

The test facilities where the tests were performed are equivalent to those prescribed by the international standard EN ISO 140-1[1]. Its is formed by a reverberation room of 120 m^3 volume, in which its global ceiling integrates a partial ceiling, the current test floor made of reinforced concrete, of 0,14 cm thickness and surface mass of 350 kg m^{-2}, normally used to evaluate the impact noise reduction of floor coverings. This test floor is rectangular with dimensions of 3,42 m $\times$ 2,42 m and it is supported by a continuous resilient strip layer to avoid flanking transmission. The false ceilings were built under this floor. In figure 1 a view of this construction is illustrated.

Fig. 1 – Overview of a false ceiling constructed in the test room

TESTS AND THEORY

To evaluate the changes in performance of these systems, 3 false ceilings were constructed at a distance from the supporting slab of 15 cm, 25 cm and 45 cm. The false ceilings are made of plasterboard with rockwoll on its back surface.

To evaluate the performance of these systems against impact noise, the tapping machine was placed on the laboratory test bare floor. The sound levels spectra was recorded in the reverberation room. The efficiency of the systems was calculated with the follwing equations:

$$\Delta L = L_{no} - L_n \qquad (1)$$

where L_{n0} represents the normalised impact sound pressure level in the receiving room produced by the normalized tapping machine hammer impacts on the bare floor and L_n the averaged sound pressure established in the same room by the normalized tapping machine hammer impacts when the false ceiling was placed. In this case, the parameter ΔL represents the efficiency of the ceiling in frequency bands. Both L_{n0} and L_n are expressed in dB.

The averaged sound pressure in a room in frequency bands is obtained in accordance with the following equation:

$$L = 10 \log\left(\frac{1}{n}\sum_{j=1}^{n} 10^{L_j/10}\right) \quad dB \qquad (2)$$

where L_j are the sound pressure levels.

To evaluate the false ceilings performance regarding airborne noise the sound source was placed inside the reverberation room, originating a noise emission field which consequently establishes levels of vibration on the ceiling slab.

$$< v_n^2 > = \frac{\omega^2 F_\omega^2}{S^2 m^2} \sum_n \frac{1}{\left(\omega_n^2 - \omega^2\right)^2 + \eta_d^2\, \omega_n^4} \qquad (3)$$

This vibration field, mainly due to the propagation of bending waves, is directly converted into radiated noise and to a sound field in an enclosed space, by means of application of theoretical formulas, and the corresponding radiation factors, as follows:

$$< P_i > = \sigma \rho_0 c S < v_i^2 > \quad \text{and} \quad < p_i^2 > = 4 < P_i > \rho_0 c / A \qquad (4)$$

being

$$\sigma = \frac{1}{\sqrt{1 - \frac{f_{cr}}{f}}} \qquad (5)$$

Additionally, the sound field established into the cavity defined by the false ceiling and the structural slab (test floor) were recorded in order to evaluate the eficiency of the rockwool for the purpose of reducing the sound field in that cavity, making use of its absorption coefficients previously determined using the stationary waves tube (Kundt).

RESULTS

In the following figures the acoustic efficiency of these false ceilings is presented, both for airborne and impact sound insulation. For the impact sound, the efficiency was calculated from the established relations between the velocity vibration levels of the panel, considering the performance of each system. Regarding the airborne sound, the efficiency was calculated based on the performance of each system from the values of vibration velocity. By the fact that was not possible to measure the vibration velocity with enough degree of reliability - the test floor is hardly dissipative -, the calculations were made till the frequency band of 1 kHz. In this case was not advisable to determine the noise insulation index of the system, but it is possile to make an ideia of its performance in frequency domain.

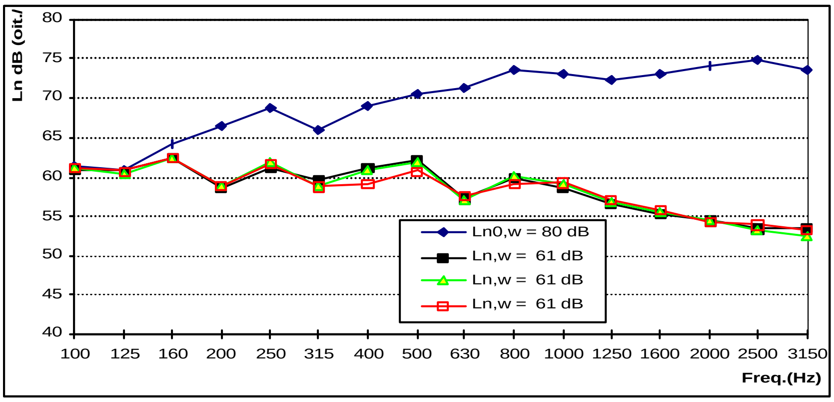

Fig. 2 - Impact sound insulation of each false ceiling

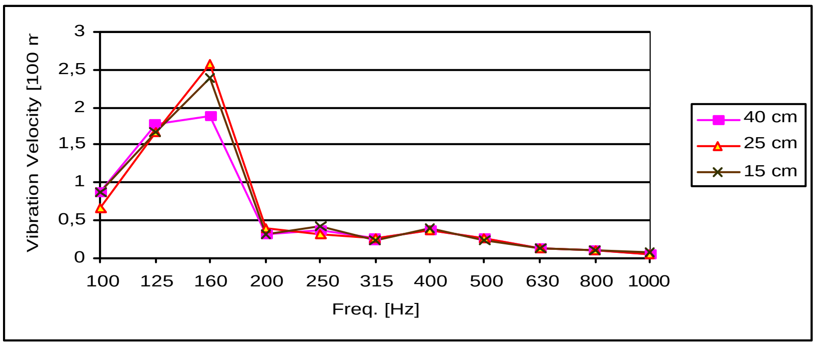

Fig. 3 - alse ceilings performance regarding airborne sound

In figure 4, the sound field established inside the cavity defined by the false ceiling and the test floor is presented.

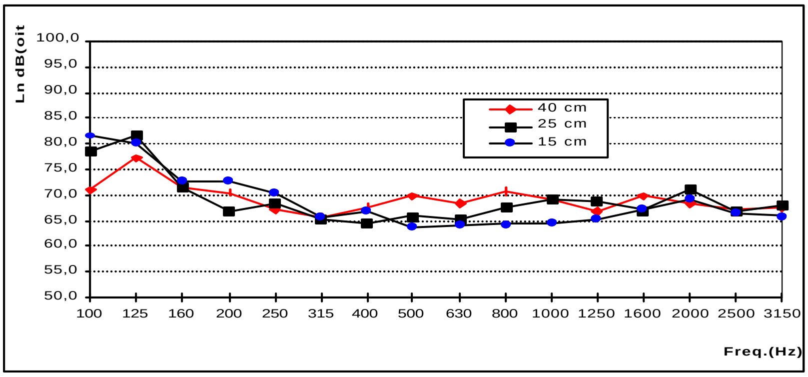

Fig. 4 - Sound field distribution inside the false ceiling cavity

As a complementary information, some data regarding the material characteristics and some theoretical parameters related to the acoustic fields of the cavity, are presented in the next two figures and in table 1.

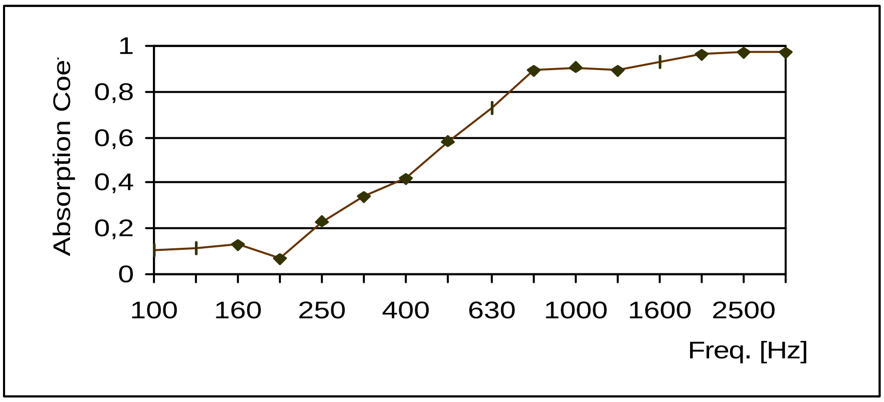

Fig. 5 – Absorption coefficients of the rockwool.

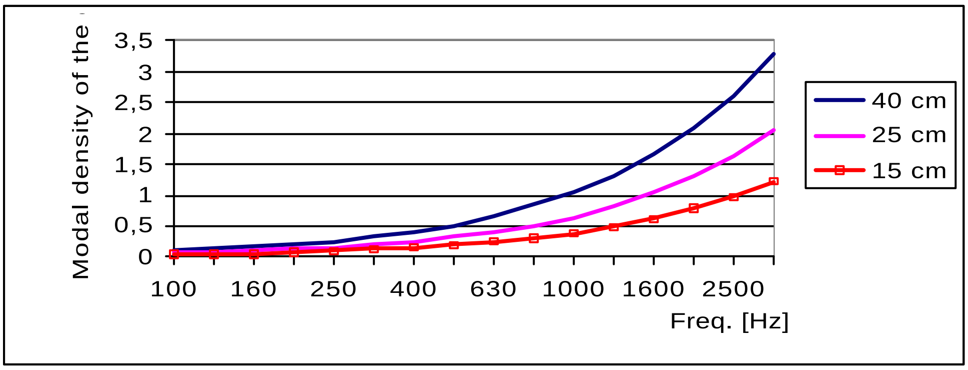

Fig. 6 - Modal density of the cavity defined by the false ceiling and the slab

Table 1 - Cavity resonances

$f_n = n\,c\,/\,(2\,d)$ (Hz)			Value of n
d = 40 cm	d = 25 cm	d = 15 cm	
425	680	1133	1
850	1360	2267	2
1275	2040	3400	3
1700	2720	4533	4
2125	3400		5
2550			6
2975			7
3400			8

d – distance between the false ceiling and the ceiling slab; c – sound velocity in the air; and n – integer number.

The frequency resonance of the mass-spring system is below the frequency range of interest (20 Hz for 40 cm distance; 25 Hz for 25 cm distance and 32 Hz for 15 cm distance), which turns it no influent on the system performance.

CONCLUSIONS

Based on this experimental work, several conclusions may be extracted. They are respectively the following ones:

1. The false ceiling efficiency is not influenced by the considered range of distances at which it was constructed from the ceiling slab, both for impact sound and airborne sound;
2. The missing of variations regarding the efficency of this false ceilings with the distance to the ceiling slab may be due to the fact that the false ceiling had to be rigidily suspended. But this is the normal usage.
3. The efficiency of false ceilings can be increased in accordande with the values of sound absorption coefficients of the rock wool or other similar material. The porosity of these products will increase the sound insulation of all the system (false ceiling plus ceiling slab) in medium and high frequencies. On the other hand and because of the resonant panel effect, their density will increase the sound insulation in the low frequencies.
4. The value of coincidence frequency of the ceiling slab is really highlighted, confirming the theoretical predictions for the test floor (frequency band of 160 Hz).
5. The solutions tested are of capital importance for correction of interfaces between residential areas (flats) and adjacent commercial zones (shops and so on).

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