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Architectural acoustic design using absorption materials: the case study "Snooze Panel"

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ABSTRACT

The Snooze ® sound-absorbing panel is the result of the necessity to characterize an architectural space such as offices, corridors, classrooms, hospitals while guaranteeing the required acoustic characteristics using renewable materials. An experimental case study is proposed showing how different chooses in panel assembly arrangement are affecting its acoustic performance. The proposed procedure allows evaluating the acoustic properties of a panel assembly, specifically the rating of sound absorption according to the EN ISO 11654 i.e. the weighted sound absorption coefficient a_w, considering the intrinsic panel characteristics and the different types of installation with variable distance from the wall surface behind the panel. While the material characteristics can be assessed in laboratory using appropriate instruments as explained, the acoustic behavior of the panel due to the geometry and installation solutions are evaluated in actual assembly in reverberation chamber according to the standard EN ISO 354.

Keywords: absorption, insulation, measurements

1. INTRODUCTION

An architectural space is intrinsically sonorous; it is characterized by its own musicality and resonance depending on volumes, materials and shapes that define it.

The Snooze® panel can be an architectural element that satisfies aesthetic requirements while guaranteeing the required acoustic characteristics of the space. It can be successfully used most of the times, when solutions to improve the space acoustic quality are taken into consideration and proposed only in the executive phase of the project and not together with the architectural design.

The proposed procedure allows evaluating the acoustic properties of a panel assembly, specifically the rating of sound absorption according to the EN ISO 11654 (1) i.e. the weighted sound absorption coefficient, $\alpha_{w,}$ considering the intrinsic panel characteristics and the different types of installation with variable distance from the wall surface behind the panel.

The material characteristics are assessed in laboratory using appropriate instruments following different standards (2), (3), the acoustic behavior of the panel due to the geometry and installation solutions are evaluated in actual assembly in reverberation chamber according to the standard EN ISO 354 (4).

2. MATERIALS AND METHOD

The Snooze® panel is made of hot-moulded polyester fibre, the absorbing material. The shape is square 630 x 630 mm with rounded corners (Figures 1 and 2). The absorbing material is then covered with a synthetic lining.

This work aims to report about an assessment procedure for a panel assembly that can help to design an assembly able to reach the absorption class A as defined by the ISO 11654, showing the influence of different design parameters as the material density, the mounting and the use of a liner.

The single-number rating specified in this International Standard can be used to formulate requirements and to describe acoustical properties of sound-absorbing products to be used for applications in offices, corridors, classrooms, hospitals, etc.

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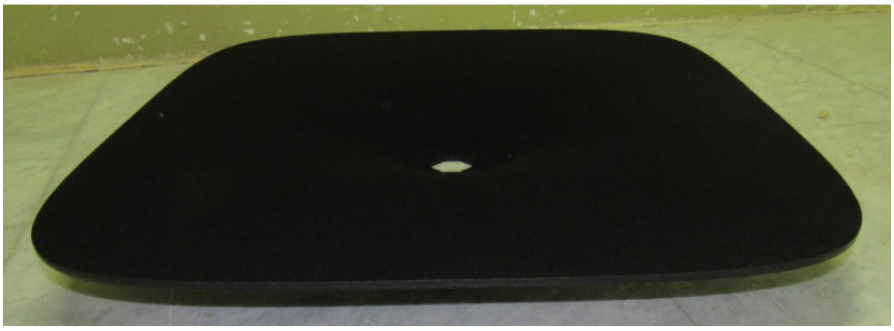

Figure 1: panel without lining

Figure 2: panels with the lining on the reverberant chamber floor

The rating is not appropriate when the products are to be used in environments requiring special careful acoustical design. In such cases, only complete sound absorption data as a function of frequency are satisfactory.

As the rating curve in this International Standard has as a lower limit the 250 Hz octave band, the rating is not appropriate below this frequency. If such low frequencies are of interest, reference must be made to the complete sound absorption curve.

In this paper, much attention is given to the absorption class, but the measured absorption curve is also reported.

In particular, to improve the abortion properties different solutions are considered and combined together, without changing the assembly panel shape and dimensions as defined by the Architects; these potential improvements are:

- an higher density of the polyester fiber instead of a low density polyester;
- the increasing of the air gap behind the panel;
- a lining improving the sound absorption properties of the panel

As explained in the literature, improving the density of an absorption material, the sound absorption coefficient grows up at low frequencies and decrease slightly at higher frequencies (Figure 3).

The influence on the acoustic absorption coefficient of the panel assembly has been investigate comparing two equally shaped panel assemblies made with different densities (40 kg/m^3 and 80 kg/k^3).

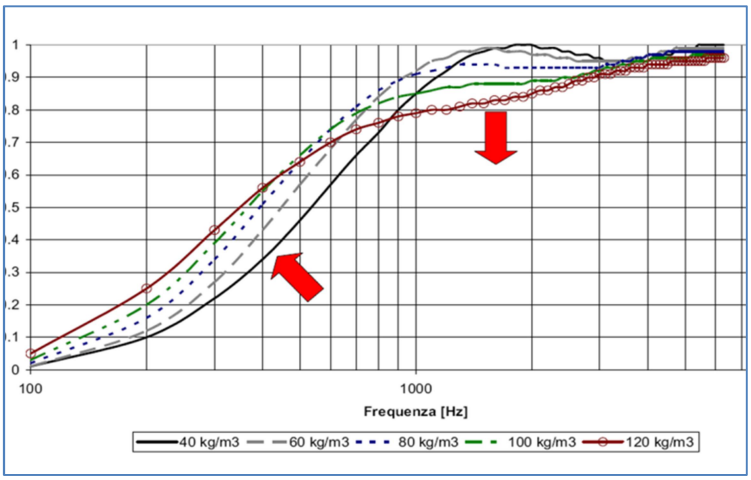

Figure 3: the density effects in a porous panel (fibreboard thickness 40 mm)

Regarding the air gap behind the panel, if a thin porous absorber is positioned such that it has an airspace behind it, the composite impedance at the surface of the material, and thus the absorption coefficient α,is influenced by the backing. This influence has been analysed in a comparative way assessing the acoustic performance of a pane assembly without and with a specified air gap behind.

The lining can have different characteristics. It can be transparent to the sound, i.e. the sound goes through without any absorption, or it can be characterized by a specific flow resistance, according to the EN 29053 (5), which can contribute to improve the overall sound absorption. To assess the influence of the usual liner covering such kind of absorber, measurements on the same assembly with and without the liner have been carried out.

3. Results and Discussion

3.1 Reverberant chamber measurements

Description of test environment in the reverberant room follows in Table 1:

Table 1: test environment

Room volume V	191 m^3
Room surface S_0	244 m^2
Diffusers surface S_t	35 m^2
Sound source positions:	4
Reference test area = 11,1 m^2	11,1 m^2

Five different configurations are tested:

- n° 30 panels, density 80 Kg/m3, on the floor, without lining
- n° 30 panels, density 80 Kg/m3, on the floor, with lining
- n° 30 panels , density 40 Kg/m3, on the floor with lining
- n° 30 panels with lining and 200 mm air gap behind, with lining 40Kg/m3
- n° 30 panels with lining and 200 mm air gap behind, with lining 80Kg/m3

The results follow in Table 2 and in Figures 4-6:

Table 2: Sound absorption coefficient (α) in third octave bend

Hz	panel, density 80 Kg/m^3, on the floor, without lining	panel, density 80 Kg/m^3, on the floor, with lining	panel , density 40Kg/m^3, on the floor with lining	panel with lining and 200 mm air gap behind, 40Kg/m^3	panel with lining and 200 mm air gap behind, 80Kg/m^3
	α_w 0.70 Class C	α_w 0.80 Class B	α_w 0.80 Class B	α_w 0.90 Class A	α_w 0.95 Class A
100	0,05	0,11	0,08	0,15	0,16
125	0,04	0,05	0,05	0,1	0,13
160	0,08	0,15	0,14	0,23	0,25
250	0,36	0,5	0,47	0,59	0,67
315	0,54	0,73	0,7	0,78	0,9
400	0,74	0,98	0,93	0,91	0,99
500	0,86	1,13	1,04	0,95	1,06
630	1,03	1,21	1,08	0,95	0,99
800	1,12	1,2	1,14	1,03	1,07
1.000	1,14	1,18	1,09	1,11	1,14
1.250	1,11	1,11	1,06	1,11	1,14
1.600	1,08	1,07	1,02	1,14	1,17
2.000	1,06	1,06	1,01	1,14	1,18
2.500	1,02	1,05	1,02	1,15	1,19
3.150	1,03	1,07	1	1,13	1,21
4.000	1,02	1,02	0,96	1,1	1,18
5.000	0,97	1	0,92	1,04	1,13

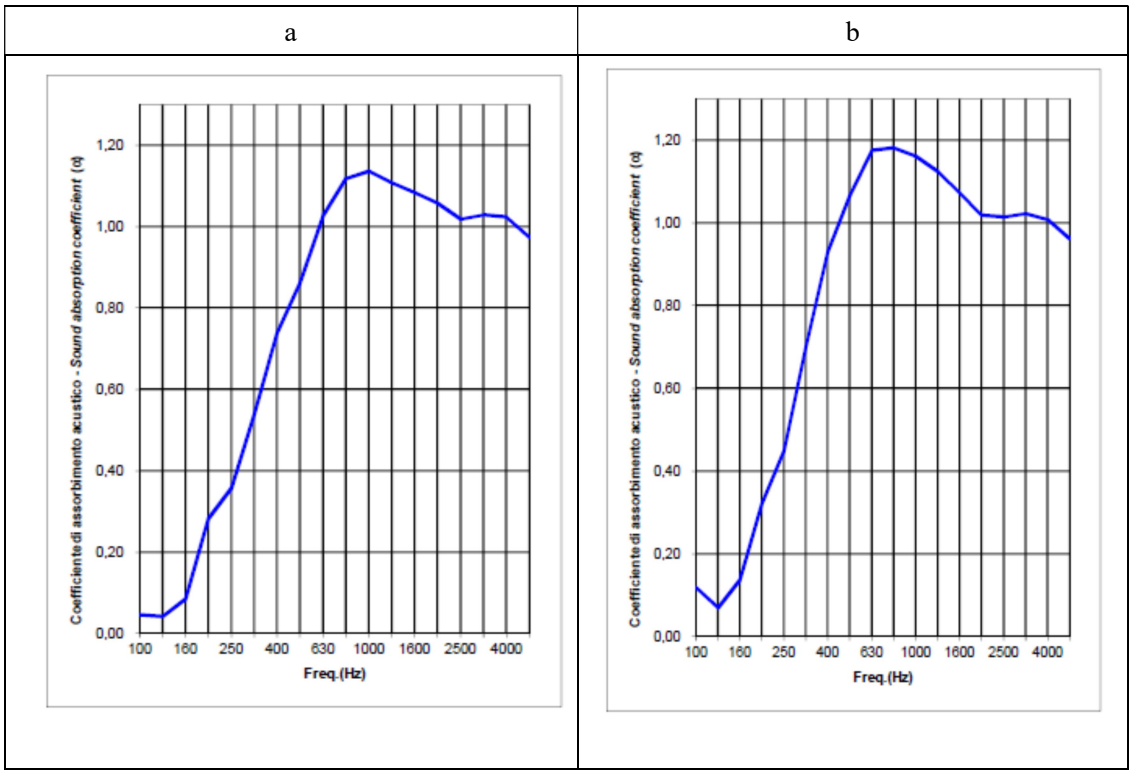

Figure 4: panel, density 80 Kg/m^3, on the floor: (a) without lining, α_w 0.70; (b) with lining α_w 0.80

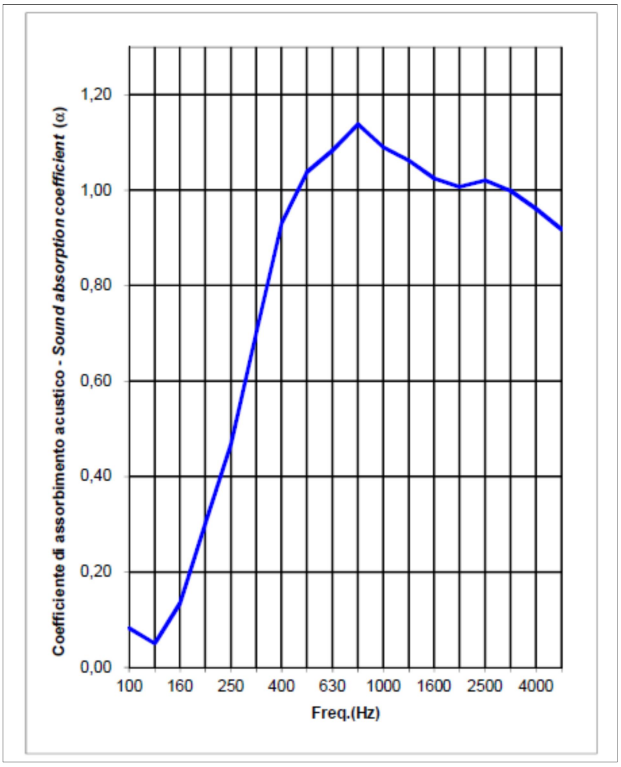

Figure 5: panel on the floor with lining , density 40Kg/m^3, α_w 0.80

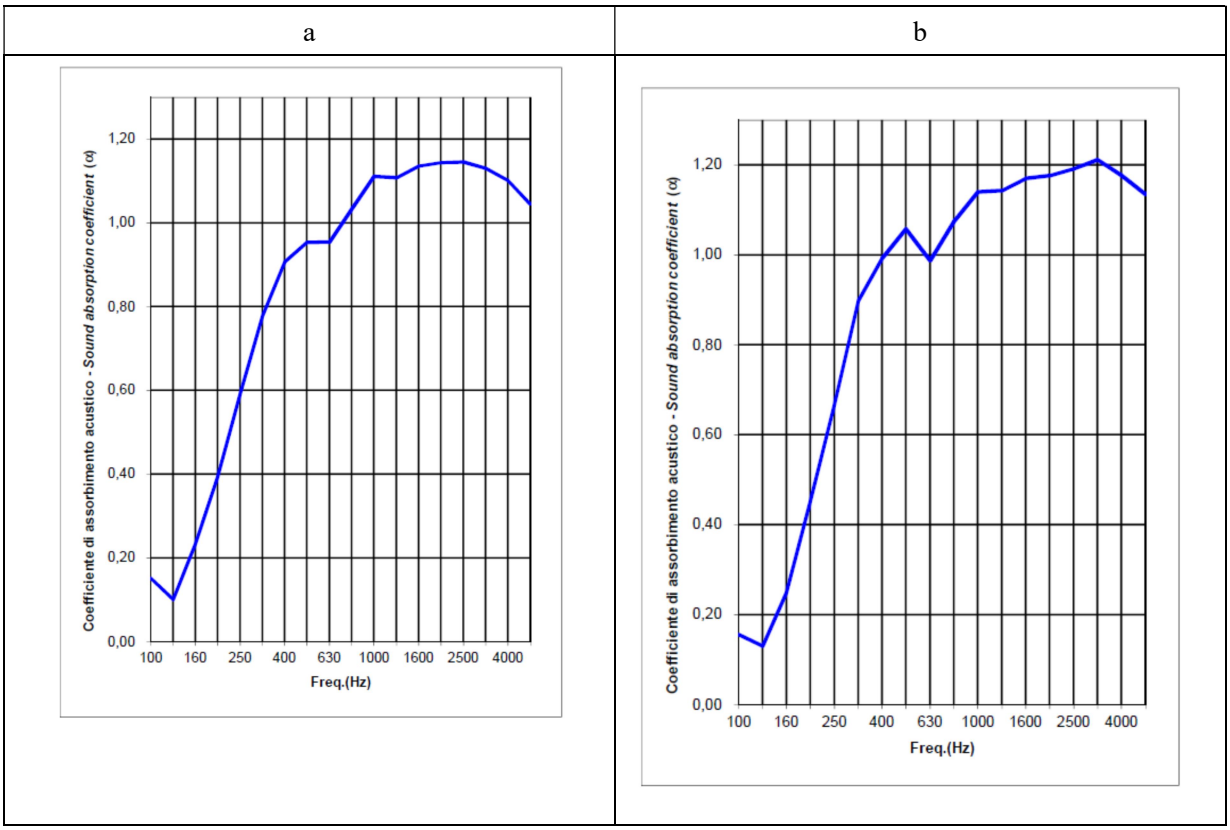

Figure 6: panel with lining and 200 mm air gap behind, (a) 40Kg/m3 α_w 0.90, (b) 80Kg/m^3 α_w 0.95

At first, the lining properties are investigated comparing the absorption coefficients of the same panel assembly with and without lining, density 80 Kg/m^3. The deviation of the absorption coefficient is defined as it follows:

$$D = (\alpha_2 - \alpha_1)/\alpha_1 \quad (1)$$

α_1 is related to the panel without lining and α_2 to the panel with lining

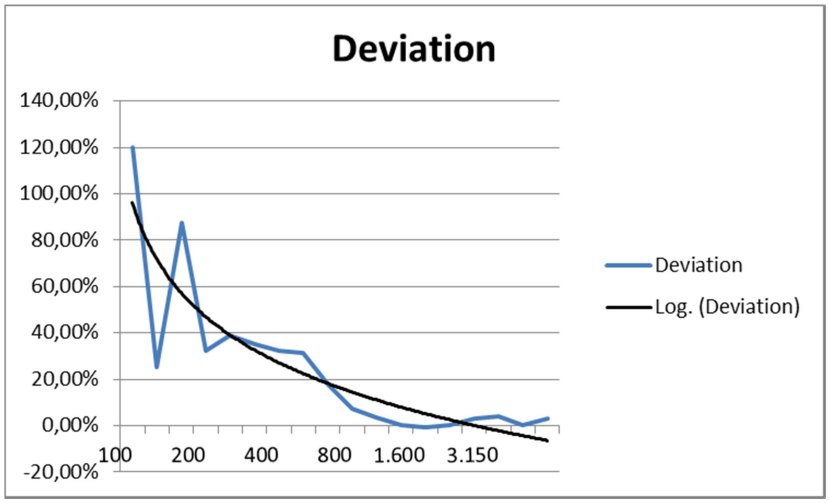

Figure 7: absorption coefficient deviation due to the lining

The lining increases the absorption coefficient in all the considered range of frequencies. At lower frequencies, the contribution is much more significant but also up to 250 Hz and, at central frequency,

there is an improvement that can be considered useful to improve the absorption Class of the panel.

The second consideration is about the material density.

The absorption coefficient deviation of the panel assembly on the floor is studied. In this case, α_1 is related to the panel without lining, density 40Kg/m^3, and α_2 to the panel with lining, density 80Kg/m^3.

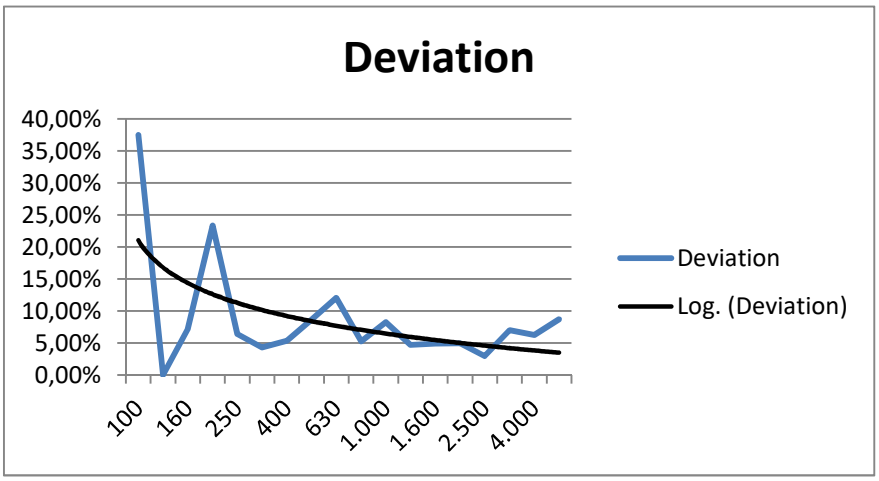

Figure 8: absorption coefficient deviation due to the material density

The highest absorption coefficient increasing due to the density improvement is at low frequencies while up to 250 Hz the phenomenon is present but does not increase the absorption class of the panel.

The third study is the deviation due to the air gap for both the panels with a density 40Kg/m^3 and 80 Kg/m^3 (α_2) in comparison with the same panels on the floor (α_1).

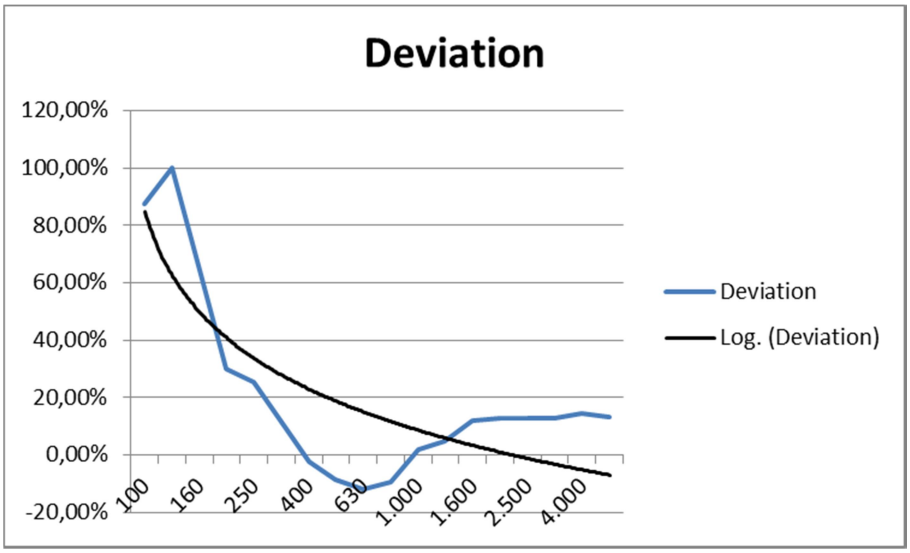

Figure 9: absorption coefficient deviation due to the air gap, density panel 40 kg/m^3

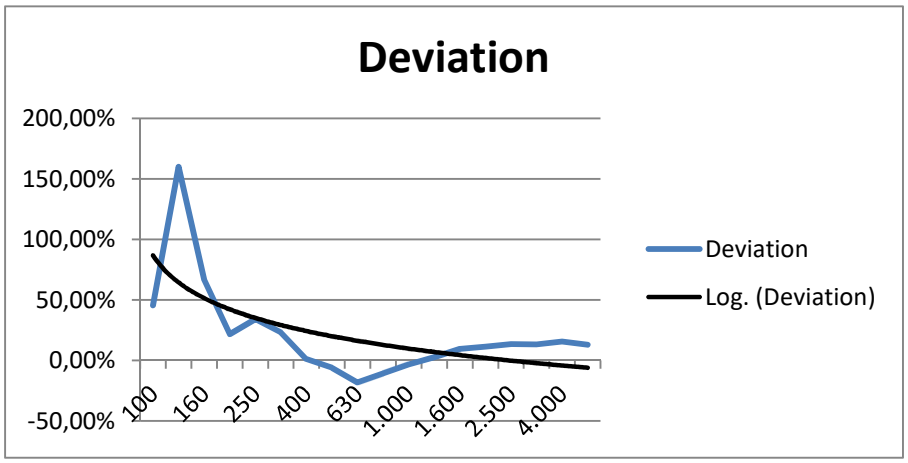

Figure 10: absorption coefficient deviation due to the air gap, density panel 80 kg/m^3

The air gap does not improve the absorption coefficient at central frequencies between 400 and 1500 Hz, but, because the absorption coefficient increases outside this range especially at low frequencies, the sound absorption coefficient, α_w increases in both cases.

4. CONCLUSIONS

The lining proposed at first by the architects, for aesthetic reasons, is considered to increase the absorption coefficient and it is introduced in any possible configuration.

The panel with 40 kg/m³ allows performances between class B and class A where it is progressively distanced up to 20 cm from the wall (for example for ceiling applications). Moreover, its absorption spectrum on the typical frequencies of the word (from 250 to 4000 Hz) is always higher than 0.5, with absorption at the central frequencies of the speech close to 100%, obtaining great effectiveness on the intelligibility of the phonemes and therefore of the language.

The panel with density equal to 80 kg/m³, applied to the wall, allows performance close to class A. In particular where it is progressively distanced up to 20 cm (ceiling application), class A is widely achieved. The minimum absorption at the medium-low frequencies (250 Hz) is higher than 67%, while on the higher frequencies it is always maximum (100%), resulting in the maximum efficiency in terms of speech intelligibility.

For a high acoustic performance space, it is then reasonable to propose the standard weight panel with a density of 80 kg/m^3 with the standard liner, which gives an A class as result, even if mounted very close to the surface.

ACKNOWLEDGEMENTS

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