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Impact sound insulating performance of access floors

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Access floor are raised floor systems consisting of modular panels supported by posts at a certain height to create a gap below the floor surface. Electrical wires and pipes can be conveniently placed inside the gap in order to avoid exposed installations and to simplify operations involving the inspection, repair, changing or adding of system elements. This paper presents the results of two measurement campaigns carried out using the procedures given by EN ISO 140-6 and 140-12 standards. A stage of measurement has been performed on different access floor configurations, obtained by changing different floor elements, such as panels, surface finishes and damping materials under the posts base, in order to optimize their acoustic performance. Impact sound insulating properties of access floors combined with false ceilings were also tested and are reported in the paper.

1 Introduction

An access floor is a raised floor system consisting of modular panels supported by steel posts, placed at a certain height to create a gap below the floor surface. This hollow space can be efficiently used for data transmission, automation, processing, telephone network cabling and electrical wiring, avoiding unattractive exposed installations and offering great flexibility for operations involving the inspection, repair, changing or adding of system elements (Fig. 1). Moreover a wide range of finishes can be applied over the panels (tiles, carpet, parquet, lino, etc…). For these reasons access floors are becoming widely used especially in the building of office centres and working environments.

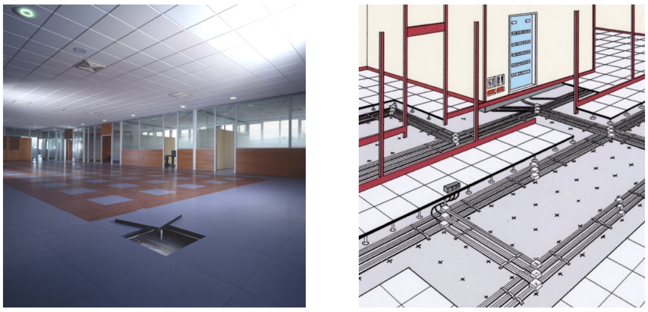

Fig.1 View of an access floor (left) and scheme of installation (right)

Though widely used, the acoustic performance of these systems have not been deeply analyzed yet, as only generic information can be found in the commercial brochures and also no scientific papers can be found in the Literature.

Therefore the goal of the present paper is to measure and analyze the global acoustic performance of access floors in terms of lateral impact sound pressure level and lateral airborne sound insulation between two adjacent rooms, having the access floor in common, and of impact sound pressure level between two overlapping rooms.

A previous paper of the same Authors [1] investigated the measurement methodology given by the standard EN ISO 140-12 [2] to measure the acoustic performance of access floors in terms of lateral airborne and impact sound insulation $L_{n,f}$ and $D_{n,f}$ and of the corresponding single number index $L_{n,f,W}$ and $D_{n,f,W}$ calculated by means of the standard EN ISO 717-1 and 2 [3, 4]; for the sake of completeness, the results will be here synthesized.

Moreover the present paper reports the results of a recent experimental campaign: several tests were executed according to the procedures given by the standard EN ISO 140-6 [5] in order to analyze the influence of the different constructive elements (panels, coverings and damping material) and to optimize the performance of the floor in terms of normalized impact sound pressure level L_n. Also the use of false ceilings combined with access floors has been investigated, since this solution is commonly used in practical applications.

2 Test rooms and measurement methodology

The Acoustic Laboratory of the University of Perugia has two overlapping reverberating chambers used to evaluate the impact noise levels reduction of floor coverings according to EN ISO 140-8 [6] and two adjacent chambers used to evaluate the sound reduction index according to EN ISO 140-3 [7].

2.1 EN ISO 140-12 procedures

The European Standard EN ISO 140-12 gives a laboratory methodology to measure the airborne sound insulation and the impact sound insulation of an access floor with an air gap of defined height, mounted below a wall separating two closed rooms (Fig. 2). The propagation of sound through paths different from the air gap below the floor must be negligible. In this way it is possible to simulate the behaviour of two typical offices or adjacent rooms, having the floor in common, with the underlying gap and the dividing partition.

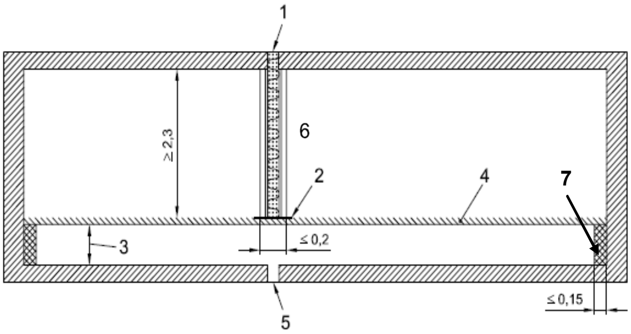

Fig.2: Requirements of the test chamber [2]: 1) and 5) elastic separations; 2) flexible material; 3) floor height; 4) access floor; 6) dividing wall; 7) sound absorbing material

The normalized lateral airborne sound insulation $D_{n,f}$ (in one-third octave frequency bands) is defined as the difference between the space-time averages of the sound pressure levels generated in two chambers by a loudspeaker placed in one of them (emitting room); the difference is then normalized with respect to a reference value of the sound absorption area in the receiving room:

$$D_{n,f}=L_1-L_2-10\log\frac{A}{A_0} \quad \text{(dB)} \qquad (1)$$

where:

- L_1 is the average sound pressure level in the emitting room;
- L_2 is the average sound pressure level in the receiving room;
- A is the equivalent sound absorption area of the receiving room;
- A_0 is the reference value of sound absorption area (in laboratory $A_0 = 10$ m^2).

The normalized lateral impact sound pressure level $L_{n,f}$ (in one-third octave frequency bands) is defined as the mean value of the sound pressure levels measured in different positions of the receiving room; the impact sound is generated by a normalized tapping machine placed in several positions on the floor of the emitting room; the value is finally normalized with respect to a reference value of the sound absorption area in the receiving room:

$$L_{n,f}=L_f-10\log\frac{A}{A_0} \quad \text{(dB)} \qquad (2)$$

where L_f is the average sound pressure level in the receiving room generated by the normalized tapping machine.

The equivalent sound absorption area A of the receiving room can be calculated from the reverberation time measured according to EN ISO 354 [8] standard, using the well known Sabine equation :

$$A=\frac{0.16\ V}{T} \quad (\text{m}^2) \qquad (3)$$

where:

- V is the receiving room volume;
- T is the receiving room reverberation time.

For the measurement of the lateral airborne sound insulation five source positions and five microphone positions have been used, for a total of twenty five measurement points (in each room) while for the measurement of the lateral sound impact pressure level four source positions and five microphone positions have been used, for a total of twenty measurement points. Furthermore background noise levels have to be acquired in order to perform the correction required by [2].

The single number ratings $L_{n,f,W}$ e $D_{n,f,W}$ are calculated through the procedures given by the EN ISO 717-1 and 2 standards; the calculations are equivalent to those used for the weighted sound reduction index R_w and for the weighted impact sound pressure level $L_{n,W}$.

The test room set-up prescribed by the reference standard is particularly laborious. The test sample is assembled in the following way: the posts are fixed on the floor of the coupled reverberation rooms and then the panels are placed upon the posts (Fig. 3); since the posts are telescopic, it is possible to level off the floor and to obtain the desired height from the floor of the room (in our tests an height of 25 cm is used); finally the panels are fixed between them by means of the top steel plates of the posts.

Fig.3: Sample mounting (left); particular of the panels and the support posts (right)

A layer of damping material (thickness = 10 mm) is placed between the access floor and the lateral walls of the test room.

In the air gap beneath the access floor a sound-absorbing mat made of rock wool (thickness = 80 mm; density = 70 kg/m^3) is placed on the two short sides of the reverberating chamber (see section in Fig. 2) and on one of the two long sides.

The wall that separates the test room is installed directly on the access floor. It has to be strongly insulating (at least 10 dB more than the access floor under test) in order to be sure that sound passes only through the air gap beneath the access floor. To that end a certified lightweight structure ($R_W = 63$ dB) is used, made of :

- double gypsum board (thickness of the single board = 12.5 mm);
- metal support structure for the rock wool insulating layer (thickness = 50 mm; density = 50 Kg/m^3);
- gypsum board (thickness = 12.5 mm) placed inside the internal air gap;
- metal support structure for the rock wool insulating layer (thickness = 50 mm; density = 50 Kg/m^3);
- double gypsum board (thickness of the single board = 12.5 mm).

A 10 mm thick antivibration layer is put between the access floor and the dividing wall.

Wall mounted absorbing panels have been installed in both the test rooms in order to reach the reverberation times specified in the EN ISO 140-12 standard. Suspended plane diffusers hanging from the ceiling allow to obtain an optimal diffuse sound field inside the test room.

2.2 EN ISO 140-6 procedures

The access floors are installed in the upper emitting chamber on the common separation floor, and the noise level is measured in different positions of the lower receiving room, separated from the coupled room by a high insulating wall (Fig. 4). The samples to be tested were installed on the heavyweight standard floor (complying with EN ISO 140-8 standard) dividing the two overlapping reverberating chambers. In this way it is possible to compare the relative performance of the tested systems with a common base floor. The heavyweight standard floor is made of a homogenous slab of reinforced concrete, 13 cm thick, with a measured value of $L_{n,W}$ equal to 80 dB.

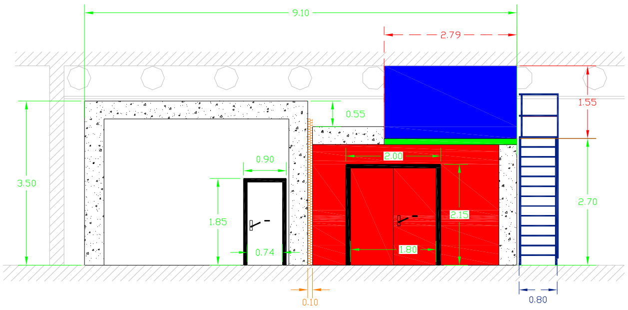

Fig.4 Section of the overlapping reverberating chambers used for the measurements

The standard EN ISO 140-6 requires to measure the normalized impact sound pressure level L_n (in one-third octave frequency bands), which is defined as the mean value of the sound pressure levels measured in different positions of the receiving room; the impact sound is generated by a normalized tapping machine placed in several positions on the floor of the upper room; the value is finally normalized with respect to a reference value of the sound absorption area in the receiving room:

$$L_n = L - 10\log\frac{A}{A_0} \quad \text{(dB)} \qquad (4)$$

where L is the average sound pressure level in the receiving room generated by the normalized tapping machine and A is the equivalent sound absorption area of the receiving room (see. Eq. 3).

Four source positions and five microphone positions have to be used, for a total of twenty measurement points. In this case background noise levels have to be acquired too.

The single number index $L_{n,W}$ are calculated by means of the standard EN ISO 717-2.

3 Description of the samples

As far as the first experimental campaign, executed accordingly to EN ISO 140-12, the tested access floor is constituted by modular panels (named CONC in the following description) installed on the entire surface of the coupled reverberation rooms; the panels were placed on the steel support posts at 25 cm from the floor of the rooms and fixed with steel plates. Then a carpet layer (thickness = 6 mm; surface mass = 4.5 Kg/m^2) was laid on the floor without using glue and another measurement campaign was carried on, in order to evaluate the improvement of the acoustical performance of the floor, especially as far as impact noise.

The goal of the second experimental campaign was to complete the analysis of the acoustic performance of the access floor tested in the first experimental campaign measuring also the impact sound pressure level between two overlapping rooms using the procedures given by the EN ISO 140-6 standard. Measurements were carried out in order to optimize the basic configuration of the access floor adding some elements (false ceiling, damping layer under the support posts) in order to improve the acoustic performance.

Therefore a total of seven configurations were tested in this second stage. The elements constituting these systems are described below:

- CONC: panel made of light cement mixture reinforced with a metal mesh and mineral fibres with a smooth upper face. Dimension of the panel: 600 x 600 x 36 mm. Surface mass: 63,9 Kg/m^2 (mass of the single panel: 23 Kg).
- GRES: panel made of light cement mixture reinforced with a metal mesh and mineral fibres with a surface finish in gres. Dimension of the panel: 600 x 600 x 42 mm. Surface mass: 70.5 Kg/m^2 (single panel: 25.5 Kg).
- PVC panel made of light cement mixture reinforced with a metal mesh and mineral fibres with a surface finish. Dimension of the panel: 600 x 600 x 38 mm. Surface mass: 65 Kg/m^2 (single panel: 23.5 Kg).
- Damping layer made of high density (750/800 Kg/m^3) vulcanized rubber to be placed under the steel support posts. Thickness: 3 mm.
- Carpet layer. Thickness: 6 mm. Surface mass: 4.5 kg/m^2.
- False ceiling made of single gypsum boards, 15 mm thick, with an air plenum of 290 mm. A rock wool layer (thickness 50 mm, density 40 Kg/m^3) is placed inside the plenum.

For the impact sound pressure level measurements the posts were adjusted so that the height of the access floor is 15 cm from the extrados of the heavyweight standard floor.

The elements constituting the seven tested configurations are reported in Table 1 (the X mark indicates the presence of the element in the configuration); configurations 1, 2 and 3 can be considered basic configurations, whereas the others can be considered optimized ones, since they combine various elements in order to improve the overall performance of the floor.

n°	panel	damping layer	carpet	false ceiling
1	CONC		X	
2	CONC	X		
3	CONC			X
4	CONC	X		X
5	CONC	X	X	X
6	GRES	X		X
7	PVC	X		X

Table 1 The various configurations of the samples under test

4 Measurement results

4.1 Lateral airborne sound insulation and lateral impact sound pressure levels

Fig. 5 reports the third-octave bands trends of the normalized lateral airborne sound insulation $D_{n,f}$, measured with and without the carpet laid on the concrete panels.

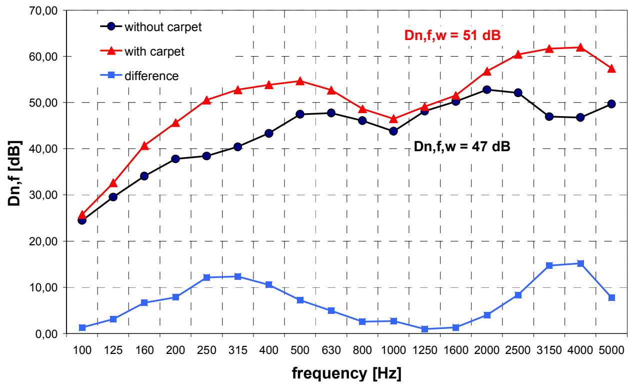

Fig. 5: Normalized lateral airborne sound insulation $D_{n,f}$ vs. frequency for the two test configuration

The application of the surface finish increases the insulating properties of the structure especially at low (160 - 500 Hz) and high (2500 – 5000 Hz) frequencies, while its effect is lower at medium frequencies; in terms of the single number index $D_{n,f,W}$ there is an increase of 4 dB. The effect of the surface finish with respect to airborne sound insulation is to cover the slits that may occur between the panels of the floor; moreover the carpet has intrinsic sound absorbing properties that influence the sound field inside the chambers.

However the effect of the carpet is much more evident for the impact noise measurements, as it can be seen in Fig.6, that reports the third-octave bands trends of the normalized lateral impact sound pressure level $L_{n,f}$, measured with and without the carpet laid on the concrete panels. with the application of the finish sound pressure levels decrease significantly in the entire considered frequency range and the single number index $L_{n,f,W}$ has a reduction of 16 dB.

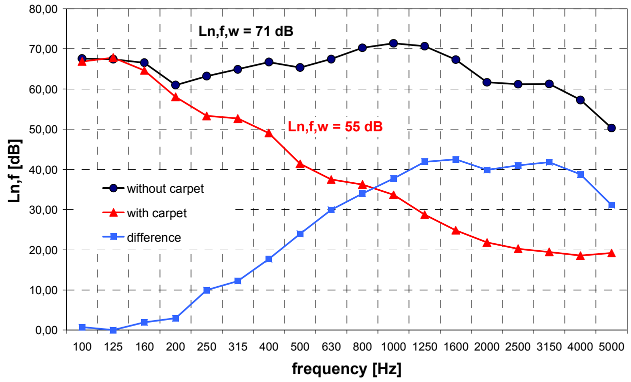

Fig. 6: Normalized lateral impact sound pressure level $L_{n,f}$ vs. frequency for the two test configuration

Therefore the use of a resilient surface finish (as carpet, lino, rubber, etc…) is strongly suggested in order to achieve adequate values of impact noise attenuation. This is also confirmed by the results given in the following paragraph.

4.2 Impact sound pressure levels

The values of the normalized sound impact pressure levels L_n in third octave bands measured for the seven configurations of access floors and for the normalized heavy floor and single number ratings $L_{n,W}$ are reported in Table 2.

	L_n (dB)							
freq. (Hz)	**stnd. floor**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
100	53,6	48,2	46,1	50,7	48,8	46,6	43,0	46,6
125	66,7	60,7	59,7	53,8	54,6	48,8	48,1	51,1
160	63,5	58,3	62,8	55,6	51,6	46,8	43,3	44,3
200	65,2	50,9	56,0	58,0	52,9	46,6	46,4	45,9
250	68,4	46,2	53,0	53,3	48,2	39,2	45,6	47,1
315	67,1	42,1	54,8	51,7	45,3	33,9	41,6	44,0
400	70,2	38,3	54,3	53,2	46,7	28,5	43,8	44,3
500	71,7	33,9	53,4	50,2	47,9	27,0	44,3	39,8
630	71,2	26,2	47,2	44,1	43,6	21,7	42,9	39,3
800	72,8	24,4	53,1	46,5	45,5	17,2	41,0	44,3
1000	73,1	21,5	49,2	45,4	39,5	13,6	42,9	37,4
1250	74	19,3	50,8	45,5	40,8	10,2	35,9	36,4
1600	74,6	17,0	50,6	42,9	38,2	8,2	34,2	33,8
2000	74,6	14,8	49,2	41,4	34,7	5,3	26,9	27,1
2500	74	14,7	45,1	39,1	32,2	5,3	23,0	22,6
3150	72,8	16,2	39,6	37,6	28,7	6,9	21,2	20,2
4000	71	11,5	33,6	32,4	22,0	4,9	16,5	13,7
5000	68,6	8,7	27,8	28,1	15,3	5,5	9,9	7,9
L_{nW}	**80**	**45**	**55**	**50**	**46**	**38**	**41**	**41**
ΔL_W	**-**	**28**	**23**	**26**	**30**	**35**	**35**	**34**

Table 2 Normalized sound impact pressure levels in third octave bands of the seven configurations and of the normalized heavy floor and single number ratings $L_{n,W}$ and ΔL_W

Table 2 also reports the values of the single number ratings of the reduction of impact noise ΔL_W calculated accordingly to EN ISO 140-8 and EN ISO 717-2 considering the access floor (and, if present, the false ceiling) as a floor covering and comparing the values of impact noise levels with those of the heavyweight standard floor alone. In this way it is possible to have an idea of the potential sound insulating performance of the access floor (+false ceiling) in the case that it is installed on other typologies of floors.

Figures 7 and 8 report the third-octave bands trends of the normalized impact sound pressure level L_n. The trend of the heavyweight standard floor is reported as a comparison (dashed line).

As far as the samples constituted by CONC panels, Table 2 and Fig. 7 clearly show that the effect of the carpet layer (sample 1) on the insulating performance of the system is definitely higher than those of the damping layer (sample 2) and the false ceiling (sample 3): also considering the single number ratings, it can be seen that $L_{n,W}$ is 45 dB for sample 1, 50 dB for sample 2 and 55 dB for sample 3.

This is an expected results as the hammers of the tapping machine hit the soft surface of the carpet layer instead of the hard surface of the concrete panels, so that both the impact noise and the diffuse noise inside the emitting chamber are drastically reduced. Furthermore the reduction gets higher with increasing frequencies.

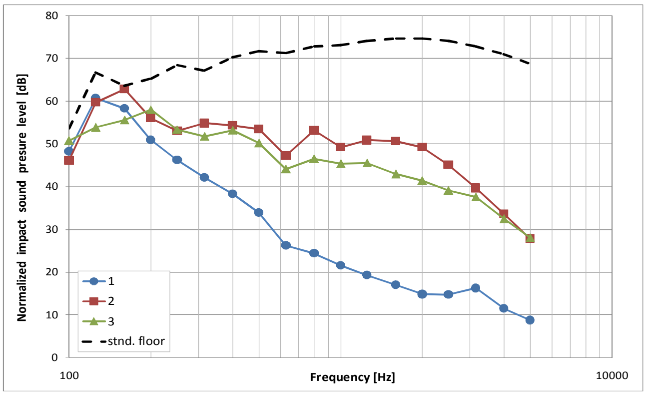

Fig.7 Normalized impact sound pressure level L_n vs. frequency for samples n° 1, 2 and 3

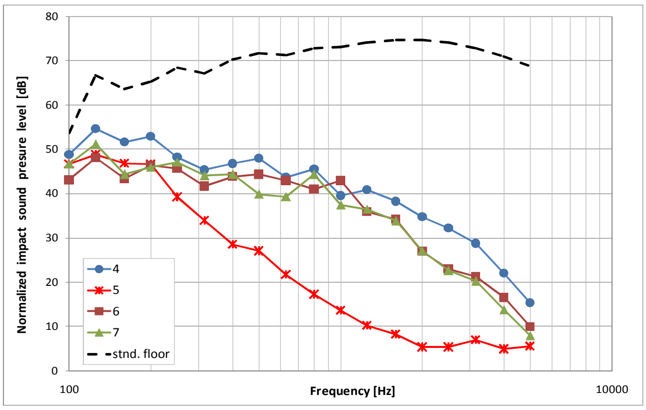

Fig.8 Normalized impact sound pressure level L_n vs. frequency for optimized samples n° 4, 5, 6 and 7

The lowest impact sound pressure levels (and the best insulating performance) are achieved by sample 5 (see Fig. 8 and Table 2); for this configuration $L_{n,W}$ is equal to 38 dB and ΔL_W is equal to 35 dB. Good results can however be reached without the false ceiling and the damping layer (see sample 1 in Fig. 7), with a consequent remarkable reduction of costs.

As far as the use of surface finish, Fig. 8 shows that GRES (n°6) and PVC (n°7) panels allow to obtain almost the same levels reduction in comparison with those of CONC panels (sample 4), provided with a smooth concrete finish (L_{nW} = 41 dB for sample 6 and 7 vs. 46 dB for sample 4). This is also down to the fact that PVC and GRES panels have higher thickness and surface mass than CONC panels.

5 Conclusion

Access floors, which are raised floor systems consisting of modular panels supported by steel posts, placed at a certain height to create a gap below the floor surface, are becoming widely used especially in offices and working environments.

The paper presents a complete characterization of the acoustic properties of these systems in terms of lateral airborne and impact sound insulation $L_{n,f}$ and $D_{n,f}$ between two adjacent rooms and impact sound pressure level L_n between two overlapping rooms, thus filling a gap in the Literature where no papers can be found on this matter.

The measurement procedures provided by the European Standard EN ISO 140-12 have proven to be particularly laborious, especially with regards to the test room set-up, while the execution of the measurements is quite simple. The results obtained as far as lateral airborne sound insulation and lateral impact sound pressure levels highlight on one hand the accuracy of the procedure and on the other hand the good properties of the tested access floor.

As far as impact sound pressure insulation, various configurations of access floors, combined with false ceiling or damping layers, have been tested accordingly to the European Standard EN ISO 140-3, in order to optimize the overall performance of the floor. Also these measurements have showed the good performance of these systems in terms of impact sound attenuation; however better results are achieved with a resilient surface finish.

In conclusion access floors seem to combine great functionality and flexibility with adequate conditions of acoustical comfort, but the use of a resilient surface finish over the concrete panels is strongly recommended in order to achieve adequate values of impact noise attenuation.

Acknowledgments

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