Acoustic performances of high insulation ventilating windows integrated with rolling shutter boxes[1]

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High Sound Insulation Ventilating Windows (HSIVW) have been recently proposed for noise control in buildings close to motorways or railways, where noise barriers are not effective or too expensive. These windows are characterized by good insulation performances and at the same time allow airflow through the window itself, thus allowing summer indoor ventilation and refreshment needs. In the last years at the Acoustics Laboratory of the University of Perugia various prototypes have been tested and their acoustic and airflow performances have been assessed, also verifying the influence of filtering systems in the aerator. The paper summarizes all the experimental data and in particular presents the results of a recent campaign, aimed at testing windows samples integrated with insulated rolling-shutter boxes. Sound reduction index R and single number sound reduction index R_w are evaluated; acoustic intensity measurements and analysis have also been performed, in order to verify the parts of the window which need to be optimized.

1. INTRODUCTION

The acoustic insulation of buildings shows many problems if related to the transparent openings, due to their low noise insulation properties; the airflow openings are at the same time very important when considering the indoor air quality.

In this context, a new opportunity to protect urban buildings against noise is constituted by High Sound Insulation Ventilating Windows (HSIVW), which show good insulation performances and, meanwhile, allow airflow through the window itself. Such a performance matches summer indoor refreshment needs with respect to the characteristics of Mediterranean climate.

At the Acoustics Laboratory of the University of Perugia an experimental campaign, sponsored by the Italian Motorways Society, was carried out in the last years. Twelve different samples of windows were first of all tested [1], to compare acoustic performances with airflow ones; six of them have a fan installed inside the aerator, in the other six air flow is due to a pressure difference between outdoor and indoor environment. Sound reduction index (R) and single number sound reduction index (R_w) were measured and evaluated according to the ISO 140/3-97 method [2, 3]; an original experimental facility was set up to determinate airflow rates [1, 4]. A sound intensity method (ISO DIS 15186-1) [5] was also used to determine R and R_w of the main elements (glass, aerator, frame) of the window.

Further research evaluated the influence of filters – inserted in the aerators to purify the inlet airflow – on the acoustic and airflow performances, showing that windows equipped with filters still present high sound insulation, with acceptable ventilation properties [6].

The paper presents also the results of the most recent campaign, aimed at testing windows samples integrated with insulated rolling-shutter boxes; the problem is relevant since most of the Italian buildings have windows with rolling shutters. The rolling-shutter box may represent a preferential way of

(1) The present paper is a revised and summarized version of the paper *"Sound intensity investigation of the acoustics performances of high insulation ventilating windows integrated with rolling shutter boxes"*, by F. Asdrubali and C. Buratti, which appeared in Applied Acoustics, Vol. 66, No 9, pp. 1072-1085, September 2005

sound transmission [7, 8], so that an accurate investigation of the new samples is suggested, aimed at optimizing the acoustic performances.

As in previous campaigns, sound reduction index (R) and single number sound reduction index (R_w), along with intensity measurements, were performed on the new prototypes.

2. HIGH SOUND INSULATION VENTILATING WINDOWS

Insulating properties of High Sound Insulation Ventilating Windows are due to a particular window design, which is based on the following criteria. Two separated parts (external and internal), which are joined together by means of elastic junctions, constitute the frame. Thus, vibrations induced on the external part by outdoor noise are not transmitted to the internal one. The glass is a sandwich structure (double glass) made by two plates (internal and external); the space between the plates is filled with particular gases (such as Argon), which increase the insulation properties of the entire structure.

The aerator is a box-shaped structure whose outdoor and indoor sides are equipped respectively with an inlet and outlet gate. The aerator duct walls have a labyrinth profile and are covered by acoustic absorbing material. When a pressure difference is maintained between the two sides of the aerator, air may flow through the duct while noise is absorbed on the duct walls. The aerator outlet gate is equipped with a shutter that allows to regulate air flow rate. The aerator may contain a centrifugal fan, to ensure airflow when no pressure difference is present and a filter, to purify inlet airflow. A typical section of an aerator is shown in Figure 1.

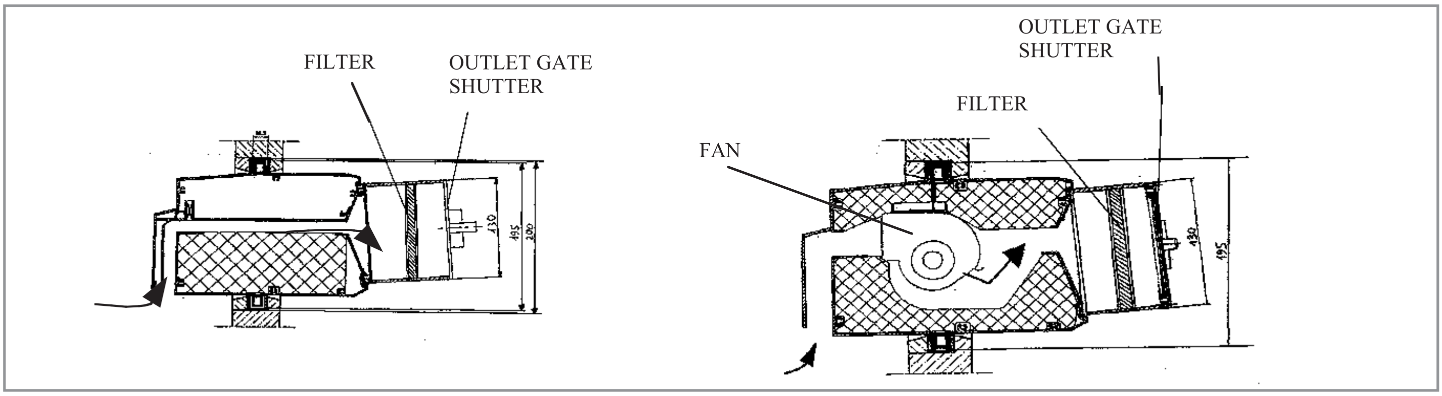

Figure 1. High Sound Insulation Ventilating Windows: aerator sections; a) without fan, b) with fan.

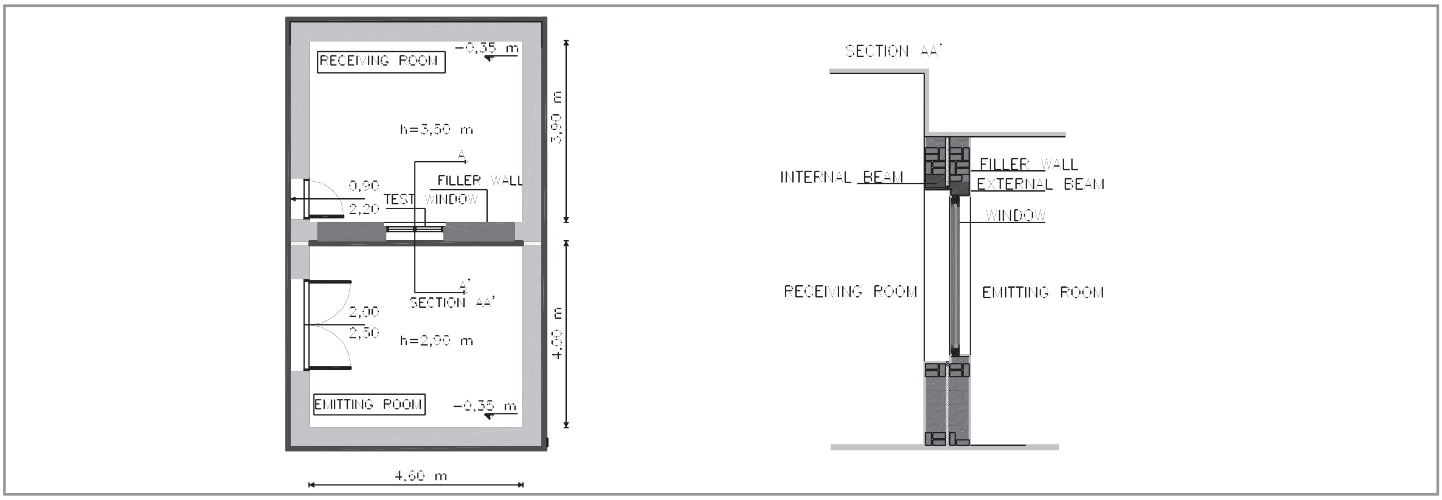

Figure 2. Coupled reverberating rooms: rooms map and sample wall section.

3. EXPERIMENTAL FACILITIES

All measurements were carried out in the coupled reverberating rooms at the Acoustic Labs of the University of Perugia. The shape and the volume of the Lab test room are in agreement with the constraints of ISO 140/1 [9]. The tested window was installed on a filler wall, which divides the emitting and the receiving room. Test room map and filler wall sections are sketched in Figure 2. R_w measurements were performed according to ISO 140/3 procedure [2, 3], by means of 2-channel real time ITT sound analyzer, equipped with software for R_w calculation. The sound source employed to excite the emitting room is a Twelve Loudspeakers Omni-directional Source; source supply signal is white noise. Also airflow rate measurements were carried out in the coupled reverberating rooms, thanks to the facility sketched in Figure 3. Determination of airflow rates versus pressure difference (ΔP) is attained as follows: a fan produces a ΔP between emitting and receiving room, set by means of an adjustable fan valve; an anemometer is installed on the receiving room outlet duct to measure the aiflow rate; a differential manometer picks up ΔP between the rooms [1]. During the airflow measurements, the rooms are pneumatically insulated from the external environment.

4. SOUND INSULATION AND AIRFLOW MEASUREMENTS ON WINDOWS WITHOUT ROLLING SHUTTER BOXES

The first experimental campaign was performed on twelve different samples of High Sound Insulation Ventilating Windows, whose characteristics are reported in Table 1.

Single number sound reduction index R_W and airflow rate measurements results are reported in Table 2 [1]. It is possible to see that R_w of the tested windows is very close to common high sound insulation windows one (30-38 dB); windows with forced convection aerators show worse performances than the ones of windows with natural convection aerators. Airflow performances are satisfactory: each sample ensures a closed window night indoor refreshment, even for a low ΔP value.

Results encouraged the execution of a second campaign, which was carried out with reference to samples n. 11 (without fan) and 12 (with fan) of Table 1, with various types of filters inserted in the aerators.

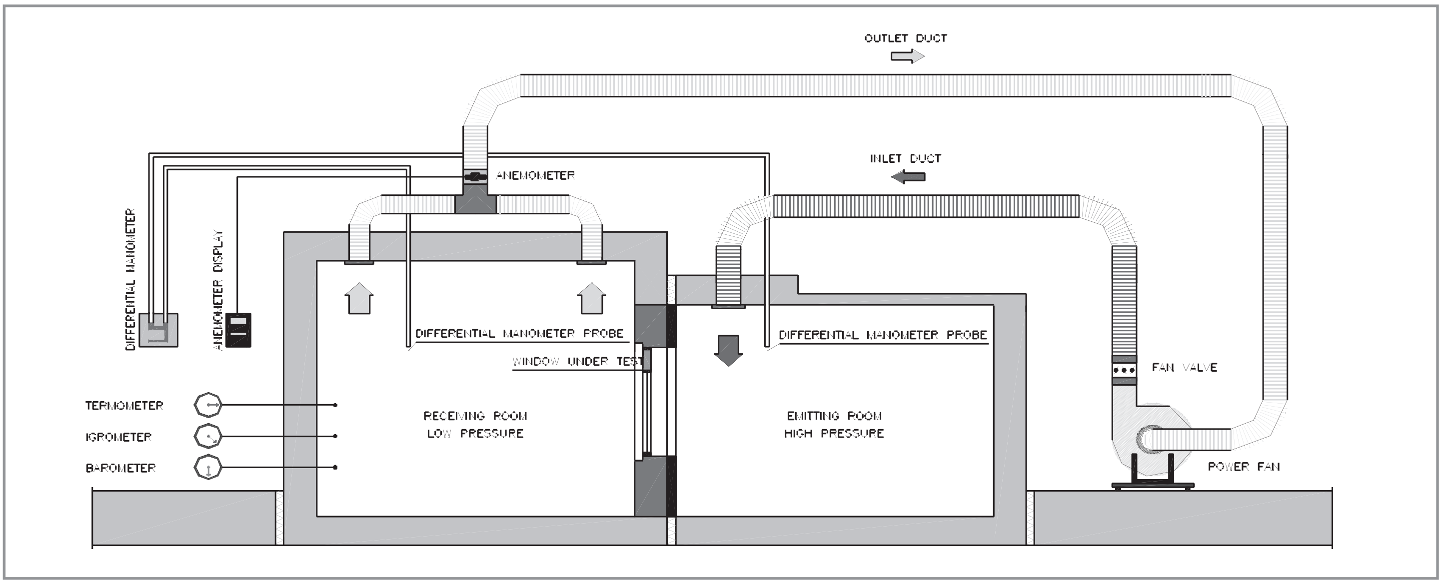

Figure 3. Airflow rate measurement facility

Table 1. Characteristics of the samples without rolling shutter box (Ar = Argon; SF6 = sulfur hexafluoride).

Sample Nº	WINDOW	AERATOR			
	Frame type	Sandwich glass thickness [mm]	Gas	Type	Fan
1	Tiltable frame	10-20-10	SF6	RENSON 43	NO
2	Tiltable frame	12-11-9	Air	RENSON 38	NO
3	Tiltable frame	12-11-9	SF6	RENSON 40/V	YES
4	Tiltable frame	10-20-10	Air	RENSON 40/V	YES
5	Simple frame	10-19-10	SF6	CIR Z150/P530	NO
6	Simple frame	10-19-10	SF6	CIR ZR – E150/P290	YES
7	Simple frame	11-15-9	Ar	SAICOVENT "NAT"	NO
8	Simple frame	11-15-9	Ar	SAICOVENT "300"	YES
9	Tiltable frame	12-20-12	Ar+SF6	ARALCO DECI – AIR K1525 – 10	NO
10	Tiltable frame	12-20-12	Ar+SF6	RENSON 40/V	YES
11	Simple frame	12-12-9	Ar	RENSON 43	NO
12	Simple frame	12-12-9	Ar	RENSON 40/V	YES

Table 2. R_W data and airflow rates of the samples without rolling shutter box, for different test conditions

Nº	RW (dB)	Fan status	Air flow rate (m^3/h)				
	Shutter opened (100%)		Shutter partially opened (50%)		Shutter opened (100%)		
			ΔP=5	ΔP=10	ΔP=0	ΔP=5	ΔP=10
1	35	Absent	169	231	/	203	281
2	30	Absent	161	217	/	189	287
3	31	Off	195	272	/	268	343
		On	/	/	272	/	/
4	31	Off	195	272	/	268	343
		On	/	/	272	/	/
5	32	Absent	55	67	/	60	73
6	34	Off	53	68	/	70	81
		On	/	/	238	/	/
7	36	Absent	140	220	/	201	259
8	31	Off	156	220	/	242	336
		On	/	/	251	/	/
9	36	Absent	106	140	/	142	170
10	31	Off	195	272	/	268	343
		On	/	/	272	/	/
11	33	Absent	169	231	/	203	281
12	28	Off	176	264	/	271	310
		On	/	/	264	/	/

Results showed that there are no significant variations in the acoustic performances of the windows, while the reduction of airflow through the aerators due to the presence of the filters is relevant (up to 50%, depending on the aerator and the kind of filter); airflow is anyway still high enough to satisfy ventilation requirements and to contribute to the building summer cooling [6].

Figure 4. High Sound Insulation Ventilating Windows with rolling shutter boxes:

5. SOUND INSULATION PROPERTIES OF WINDOWS WITH ROLLING-SHUTTER BOXES

The last experimental campaign included four different prototypes of High Sound Insulation Ventilating Windows, integrated with an insulated rolling shutter box. Most of the Italian buildings, in fact, have rolling shutters as darkening system, so the testing of such prototypes is important for a large-scale application of HSIVW. Two prototypes have an aluminium frame, the others a PVC frame; the main characteristics of the tested samples are reported in Table 3; a view of two of the samples is reported in Figure 4.

Sound reduction R measurements were performed according to ISO 140/3 and ISO DIS 15186-1/98 procedures and single number sound reduction index R_w was calculated; the results are reported in Table 4 and in Figure 5. No airflow rate measurements were carried out, since the aerators in the samples were already tested in the previous campaigns.

All the samples have R_w values bigger or equal to 33 dB; the values are in the same range of the ones of High Sound Insulation Ventilating Windows without rolling shutter boxes (33-38 dB), thus the boxes are properly insulated. In particular, sample n. 3 shows the best acoustic performances, due to an optimized design of the rolling shutter box.

Table 3. Characteristics of the samples with rolling shutter box

Sample N°	**WINDOW**			**AERATOR**	
Frame type	**Sandwich glass thickness [mm]**	**Gas**	**Type**	**Fan**	
1	Aluminum frame	9-15-11	Inert gas	Nicotra 108/176	YES
2	Aluminum frame	12-11-9	Air	RENSON AK40V	YES
3	PVC frame	10-16-10	Argon	Aeromat	YES
4	PVC frame	10-26-10	Argon	RENSON AK40V	YES

Table 4. Single number sound reduction index RW of the samples with rolling shutter boxes.

N°	**RW (dB) ISO 140-3 method**	**RW (dB) Intensity method**
	Shutter opened (100%)	
1	33	34
2	36	36
3	38	38
4	33	33

6. SOUND INTENSITY INVESTIGATION

A High Sound Insulation Ventilating Window is composed of four main elements: frame, glass, shutter box and aerator. A sound intensity investigation was carried out on the 4 samples, in order to evaluate the total sample acoustic power, the single element acoustic power and single element and total sample R_w [10, 11]. The instrumentation employed is the Aksud Symphonie two microphones intensity probe, linked to a data acquisition system equipped with software for intensity and power calculation. Intensity data were measured on each central point of a 0.2 m side square grid, built over the sample surface [11]. The distance between the grid and the sample is 0.2 m. As may be seen in Figure 6, the grid was divided into four parts; each one corresponds to a single window element. Intensity was evaluated versus 1/3 octave frequency bands; thus a 15 mm spacer was used to separate the probe microphones, in order to minimize the measurement error for 100 -5000 Hz range [11]. The emitting room sound source employed for sound intensity investigation is a Twelve Loudspeakers Omni-directional Source (TLOS), supplied with white noise. TLOS was set to produce uniform emitting room sound pressure level L_p= 106 dB for sound intensity measurements. Figure 7 shows the intensity maps for two of samples calculated by means of Symphonie package software dBFA32; it is possible to see that the aerator area shows the highest values of sound level intensity.

The sound power levels L_w emitted by the HSIVW samples elements were calculated [11] and, according to the ISO/DIS 15186-1 1998 method, the sound reduction index R versus frequency was evaluated; HSIVW elements R values are reported in Figure 8. For the samples n. 1 and n. 3 the lowest values of R were found for the shutter box, while for the sample n. 2 and n. 4, the aerator shows the lowest values of R.

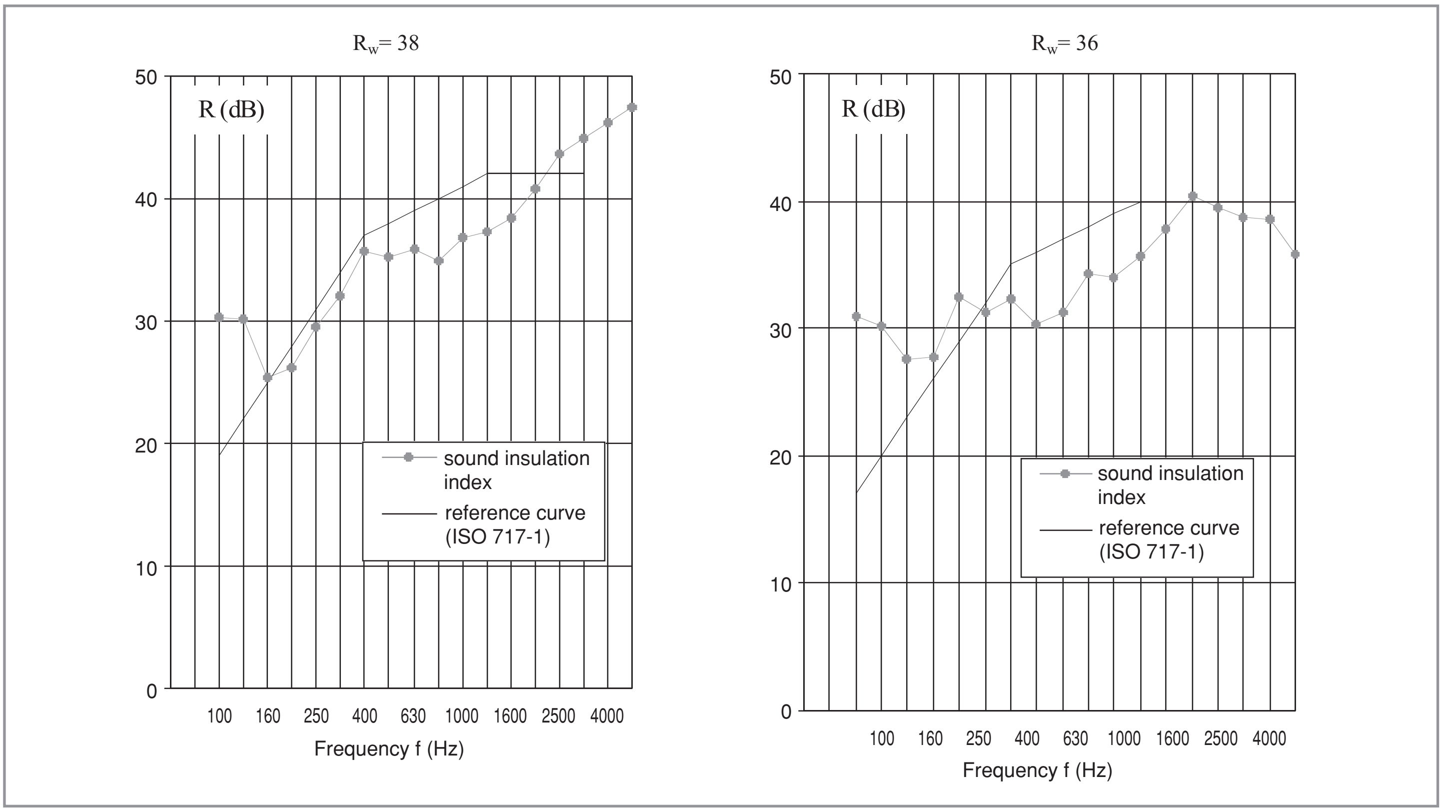

Figure 5. ISO 140-3 and 717-1 sound insulation index R vs. frequency of two HSIVW with rolling shutter box

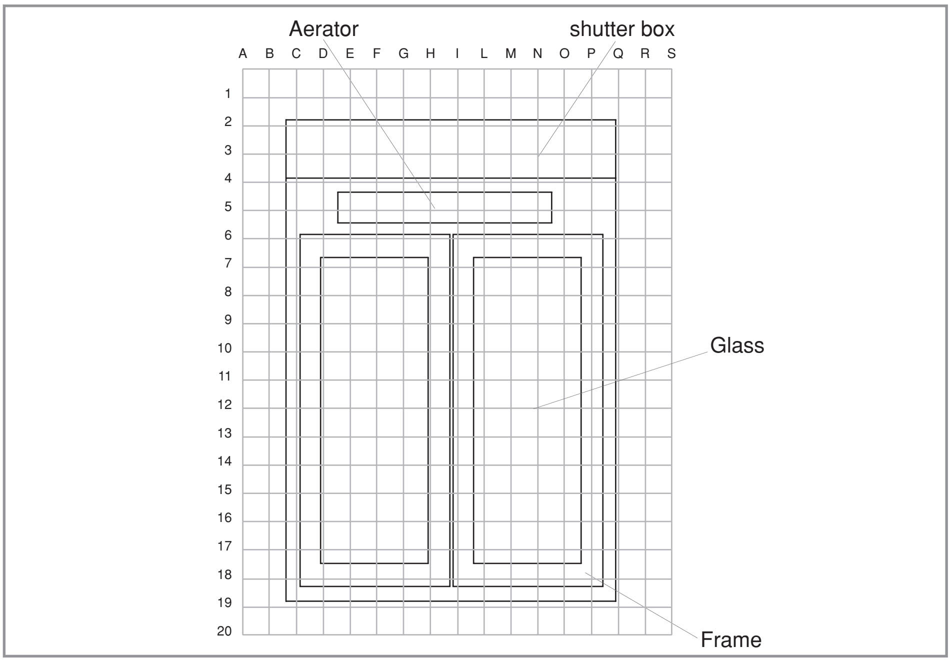

Figure 6. Measurement grid of the intensity measurements

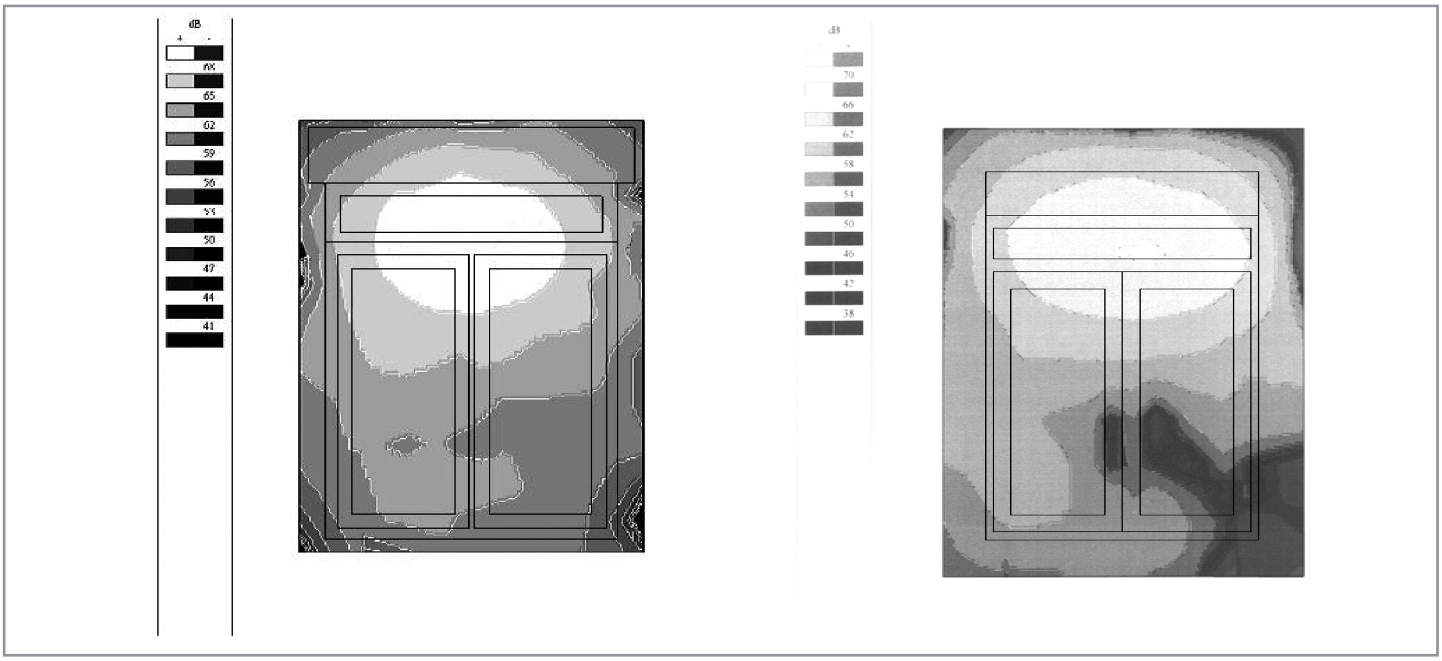

Figure 7.

Single number sound reduction index R_W was calculated starting from the two sets of data: R values measured by the intensity method (entire grid area is considered) and R values measured by the ISO-140 method; a good agreement was found between the two methodologies (Table 4).

7. CONCLUSIONS

A wide experimental investigation on different prototypes of High Sound Insulation Ventilating Windows (HSIVW), with and without rolling shutter boxes, was carried out, in order to evaluate the samples sound insulation index. These windows have been recently proposed for noise insulation in those buildings, close to a motorway or a high traffic road, where traditional noise control solutions such as noise barriers are not effective or too expensive. HSIVW, in fact, show a good sound insulation and in the meantime they allow airflow through the window itself, thanks to an aerator, thus guaranteeing indoor ventilation. More than 20 different samples were tested, with different windows, aerators, filters in the aerator, insulated rolling shutter boxes.

The paper presents in detail the acoustic performances of four different prototypes of windows, integrated with insulated rolling shutter boxes. The prototypes were especially designed and realized for the present experimental campaign, sponsored by the Italian Motorways Society. Results show that the shutter box and the aerator can be the most transmitting elements of the window, even if the differences between the various elements of the samples are not relevant. R_W values, in fact, are about the same for windows with and without shutter-boxes: so this element is very well designed in the samples examined in the present paper. High values of global R_W were obtained, in the range 33-38 dB, considering that the windows allow an airflow through the aerator.

The good acoustic performances encourage the investigation of their *in situ* sound insulation performances and eventually their industrial production. High Sound Insulation Ventilating Windows are in fact a possible solution for urban noise pollution healing. Furthermore, these windows constitute the only possible solution for cases where other noise protection systems (barriers, buffles, etc.) cannot be installed, due to the vicinity of the noise source and the receiving point or other territorial constraints.

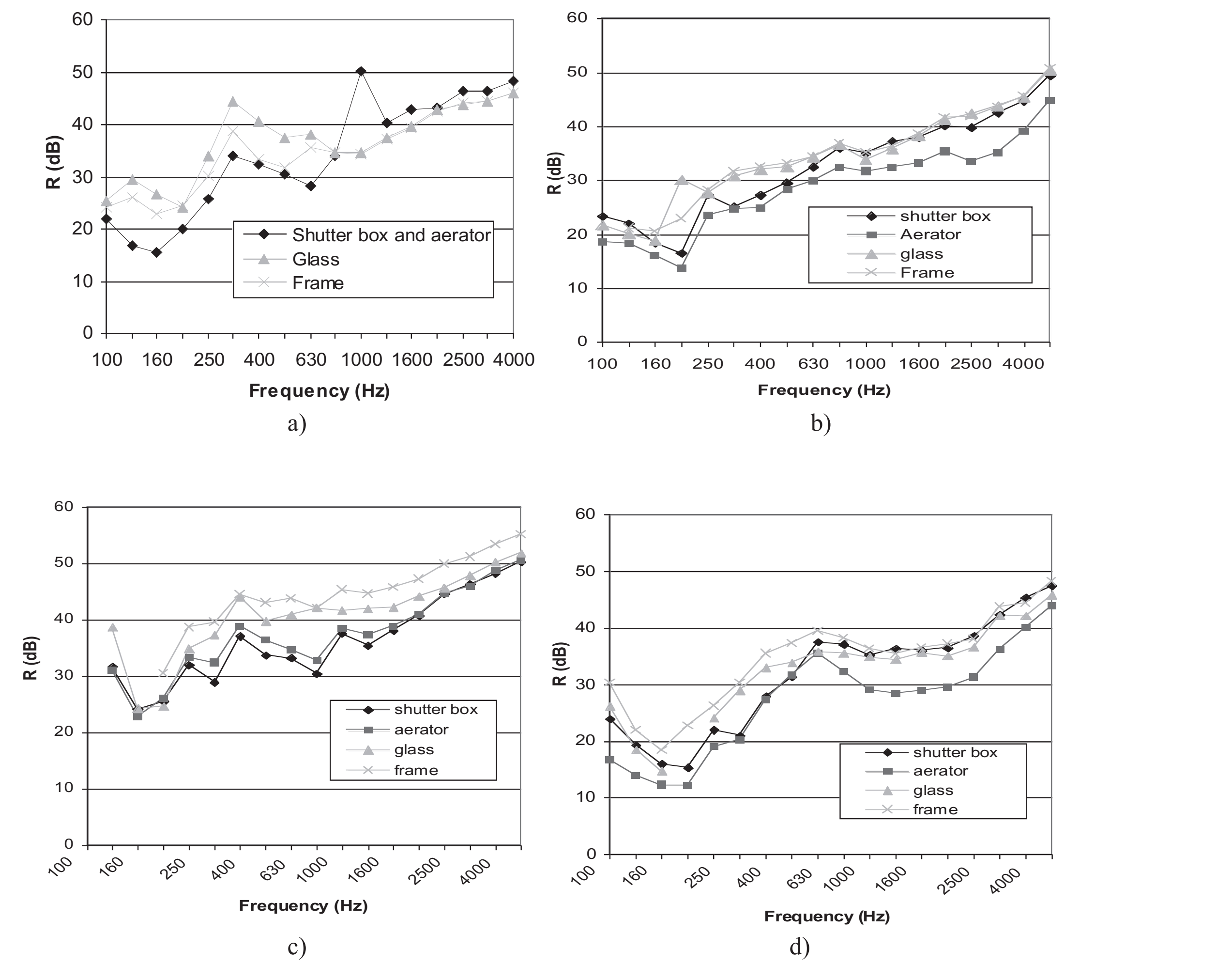

Figure 8. Sound insulation index R vs. frequency of the various samples (ISO DIS 15186-1 method): a) sample n. 1; b) sample n. 2; c) sample n. 3; d) sample n. 4.

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MEXICO CITY

As the Mexico City area continues to grow past 20 million residents, local officials say something must be done about the increasing volume. Their response is the new Environmental Standard for the Federal District, adopted in September, which cracks down on loud factories, bars, markets and other places of business in the capital. Sound levels are climbing beyond what is universally considered to be safe, said Ernesto Trujillo, head of environmental regulations for the Mexico City area. "This is not healthy," Trujillo said. "We are looking at higher levels of distress in the district due to the noise, an augmenting of stress." To show the government means business, higher fines associated with the new ordinance start around \$90 and can climb to \$900, Trujillo said. The new ordinance tightens a noise law for the area that was largely ignored after it was approved a decade ago, said Sergio Beristain, president of the Mexican Institute of Acoustics and author of a 2004 treatise on the nature of noise pollution in Mexico City. Beristain ascribed the problem to a mixture of erratic urban planning and a culture that loves to be heard. "The people, they're used to noise," he said with some resignation, calling the new law too limited in scope. "I'm not sure they have the resources they would need to enforce this ordinance. It would require a massive education campaign." Trujillo, head of environmental regulations, said enforcement would be carried out with portable sound monitors in response to formal complaints and on routine checks. Trujillo said officials also are formulating plans to quiet the sometimes-deafening roar of traffic, a task that would include widening roads, replacing creaking public vehicles and cracking down on trucks that sound like exploding bombs as they rumble over potholes.