inter-noise 2009
innovations in practical noise control
2009 August 23-26
Ottawa, Canada

Windows sound insulation: experimental evaluation of different traffic noise spectra

Cinzia Buratti[a]
Elisa Moretti[b]
Marco Vergoni[c]
Department of Industrial Engineering
University of Perugia
Via G. Duranti, 67 - 06125 Perugia, Italy

ABSTRACT

The influence of the traffic characteristics on the indoor noise transmitted by windows is evaluated by means of laboratory measurements into coupled reverberating rooms; different traffic noise spectra are registered and reproduced into the emission room, simulating the outdoor conditions; different windows are installed on the wall between the rooms and the noise spectra into the receiving room, simulating the indoor conditions, are measured and a frequency analysis is carried out. Comparing data obtained by the spectrum proposed by ISO 140 - 3 and the reproduced spectra showed no influence on the Rw value; nevertheless, considering the Ctr corrections such as in UNI EN ISO 717 – 1, significant differences were found. The A weighted levels abatements between emission and receiving room show higher values of Le – Lr for the High Speed Trian spectrum, which is the one with the lower levels at low frequencies; all windows, in fact, have worst acoustics performances at low frequencies.

1. INTRODUCTION

In the recent years there was a growing interest in noise pollution, especially in big urban areas. The design of a building also accounts for conditions of ‘‘well-being’’ noise level and intervention is often needed in pre-existing situations, where acceptable noise conditions are precarious such as near roads, railroads, airports and where the usual noise control techniques are not always sufficient; special interventions are therefore necessary, such as installing high sound insulation windows. Windows are in fact the weakest part of a façade from an acoustical point of view.

In the present paper the influence of the traffic spectrum characteristics on the indoor spectrum transmitted across different windows is evaluated, by means of laboratory measurements; they were carried out at the Laboratory of Acoustics of the University of Perugia, where two coupled reverberating rooms are available. Different traffic noise spectra are reproduced into the emission room, simulating the outdoor conditions; a window is installed on the wall between the rooms and the noise spectrum into the receiving room, simulating the indoor conditions, is

[a] Email address: cburatti@unipg.it
[b] Email address: moretti.unipg@ciriaf.it
[c] Email address: vergoni.unipg@ciriaf.it

measured; a frequency analysis is also carried out. Data obtained by the spectrum proposed by ISO 140 - 3 and the reproduced spectra are compared, in order to evaluate the variations of Rw with varying the noise source characteristics and to consider how the Ctr values calculated in compliance to ISO 140 - 3 agree with real data measured.

The A weighted levels abatements between emission and receiving room were also calculated; data obtained from the different spectra were compared, in order to evaluate the behaviour of the windows with varying the spectrum in the emission room both for Leq levels and frequency analysis.

2. EXPERIMENTAL CAMPAIGN METHODOLOGY

A. General features

In the present paper the acoustic performances of windows with varying the noise spectrum characteristics were evaluated. Measurements were carried out at the reverberating rooms of the Acoustics Laboratory – University of Perugia. In the emission room several spectra representing different traffic noise conditions were reproduced; spectra were emitted in two ways: a) such as registered on the road, for a period time representative of the real traffic noise (Signal); b) after the construction of a mean spectrum by means of the software COOL EDIT PRO 2.0 (Mean Generated Spectrum, MGS) for a period of 3 minutes (the same period for all the spectra). COOL EDIT PRO is a digital audio editor computer program from Adobe Systems featuring both a multitrack, non-destructive mix/edit environment and a destructive-approach waveform editing view.

Both Linear and A weighted abatement levels (Le – Lr) between emission and receiving room were measured; Rw data were also calculated and compared to the ones obtained from a Standard Noise, such as prescribed in ISO 140 – 3. Finally C and Ctr Indexes for the spectrum correction were calculated.

Measurements were carried out using the Symphonie system, which consists of one or two transducers (microphones, accelerometers or intensity probe) connected to a small acquisition unit (single or dual channel), which transfers data in real-time to a notebook. Many applications of this software may be addressed with 01dB application software packages; in particular. dBBATI32 allows an efficient building acoustics analysis. The instrumentations also consists of an omni-directional noise source with dodecahedral shape; two microphones (40 AR, G.R.A.S. Sound & Vibration), positioned in the emission and in the receiving room, are used to detect the acoustic signals.

B. Noise spectra

Traffic noise could generate very different spectra, depending on the road characteristics and on the vehicles rate, kind and speed. Train traffic could also generate different spectra: in particular we can distinguish spectra for High Speed Trains and Local trains.

Five road traffic noise spectra were registered in the city of Perugia and its surroundings: Freeway (FW); Urban Road (UR); Main Road (MR); Traffic Lights (TL) and Roundabout (RA). Two train noise spectra were furthermore registered: High Speed Train (HST) and Low Speed Train (LST).

Spectra were registered by a condenser microphone (diameter ½ inch, RANDOM 40AR) directly connected to the acquisition system dB-Steel SYMPHONIE and to a PC; spectra in 1/3 octave band were registered; data were elaborated by means of the softwares dBFA, dbBATI32, dBTRAIT32 and dBTRIG by 01dB-Stell. Figure 1 shows the sampling procedure.
The characteristics of the traffic noise sources considered in the present experimental campaign are reported in table 1; the spectra obtained by the measurements are reported in Figure 2, together with the spectrum proposed by UNI EN ISO 717-1 for the calculation of the Ctr Index.

C: Windows characteristics

Six different samples of windows were investigated; they could be divided into three groups:

- wood frame, section 56x68 mm, with different glasses (samples 1 and 2);
- wood frame, section 68x78 mm, with different glasses (samples 3, 4 and 5);
- aluminum frame (sample 6).

All the samples have 1220 x 1480 mm dimensions (external frame), for a total area of 1,82 m^2. The characteristics of the windows are reported in table 2.

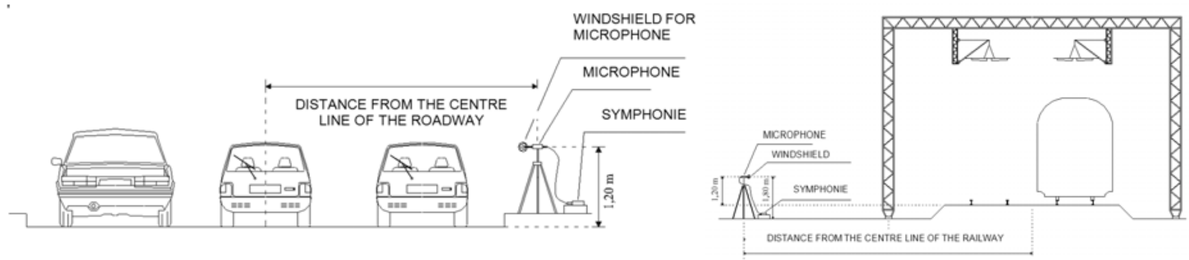

Figure 1: Sampling of traffic and train noise spectra

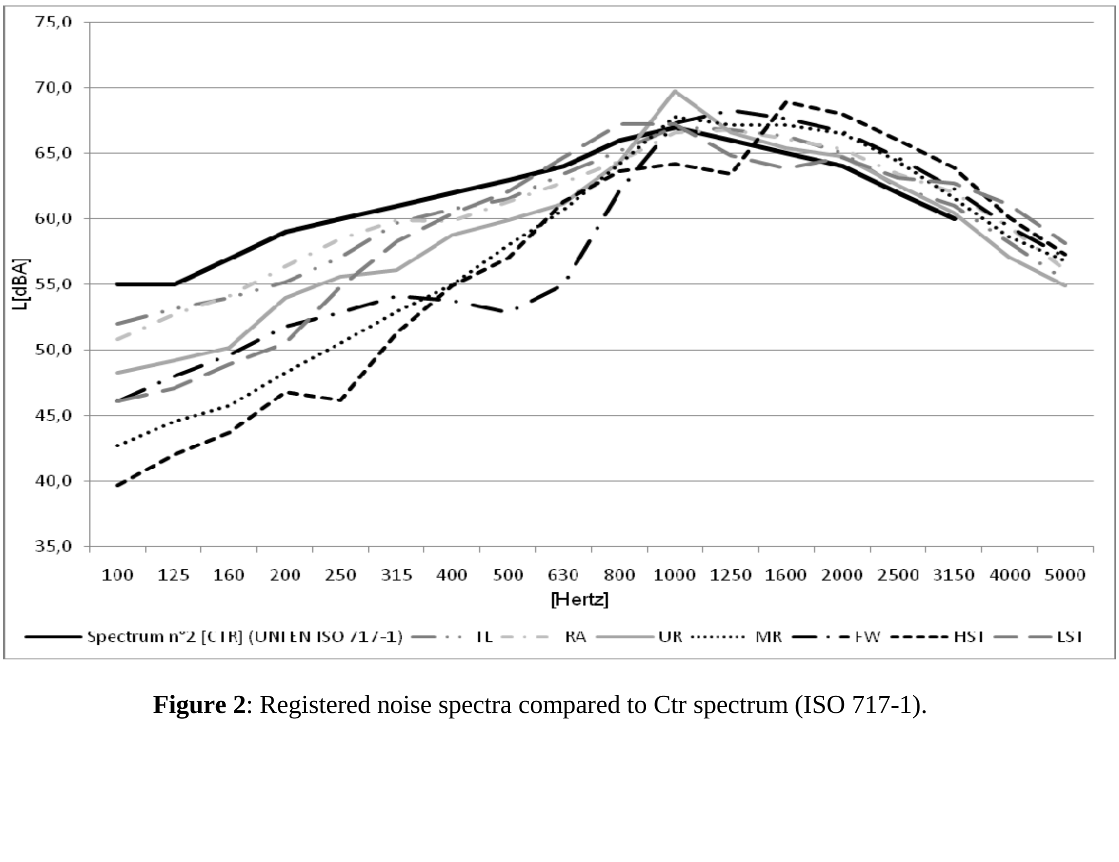

Figure 2: Registered noise spectra compared to Ctr spectrum (ISO 717-1).

Table 1: Characteristics of the traffic noise sources

Noise Source	Characteristics	Speed limit (km/h)	Traffic rate (vehicles/hour)
FW	Extra-urban Main Road, dual carriage way, each way two lanes, longitudinal slope 0%	110	980 (97% Light vehicles, 3% heavy vehicles, 0% motor-cycles)
UR	Urban sliding road, three lanes one – way, longitudinal slope 5%, went along rising	50	2050 (95% Light vehicles, 2% heavy vehicles, 3% motor-cycles)
MR	Extra-urban Road, two lanes two – way, longitudinal slope 0%	90	780 (96% Light vehicles, 1% heavy vehicles, 3% motor-cycles)
TL	Traffic-lights wit four branches	50	1154 (94% Light vehicles, 4.5% heavy vehicles, 1.5% motor-cycles)
RA	Roundabout with four entrances	50	1970 (91% Light vehicles, 8% heavy vehicles, 1% motor-cycles)
HST	Straight railway, far from level crossings	100 - 250*	-
LST	Straight railway, far from level crossings	90 - 140*	-

* train speed

Table 2: Characteristics of the investigated windows

Sample	Characteristics	Glass (mm)	Rw (dB) (C; Ctr)	Rw (dB) (not rounded value).
1	Wood (pine heartwood) frame, with mobile shutters, section 56x68 mm, rounded contours with double rabbet and acoustic gasket	4 - air 15 - 33.1a (37 dB)	38 (-2;-5)	38.3
2	Wood (pine heartwood) frame, with mobile shutters and flap, section 56x68 mm, rounded contours with double rabbet and acoustic gasket	33.1a - air 12 - 33.1 LOW-E (38 dB)	38 (-2;-5)	38.1
3	Wood (pine heartwood) frame, with mobile shutters, section 68x78 mm, rounded contours with triple rabbet and double acoustic gasket	33.1a - air 12 - 33.1 LOW-E (38 dB)	38 (-2;-5)	38.7
4	Wood (pine heartwood) frame, with mobile shutters, section 68x78 mm, rounded contours with triple rabbet and double acoustic gasket	55.1a - air 12 - 33.1a (44 dB)	41 (-2;-4)	41.1
5	Wood (pine heartwood) frame, with mobile shutters, section 68x78 mm, rounded contours with triple rabbet and double acoustic gasket	33.1a - air 12 - 33.1a (41 dB)	40 (-2;-5)	40.6
6	ALUMINIUM frame, with one mobile shutter, section 62x74 mm, rounded contours with double rabbet and acoustic gasket.	66.2a - 90% Argon 20 - 44.2 LOW-E	41 (0;-5)	41.7

3. EXPERIMENTAL RESULTS AND DISCUSSION

In UNI EN ISO 717-1 the terms C and Ctr were introduced to take into account different noise spectra, such as pink noise (C) or traffic noise (Ctr); UNI EN ISO 717 – 1 also says that in many

countries, where traffic noise is used as noise source, the obtained Rw value could be used instead of the value corrected with Ctr.
Therefore if in the emission room a traffic noise spectrum is used, Rw data must be compared to data of Rw obtained from measurements in compliance to ISO 140 – 3 and corrected with Ctr.
A comparison between Rw values obtained from the different spectra for each sample and Rw values from ISO 140 – 3 is showed in Figure 3 a) and b). Data in Figure 3 a) are referred to the signal such as registered on the road (Signal) while data in Figure 3 b) are referred to a mean spectrum generated with a software and reproduced for 3 minutes (MGS); a first consideration could be made comparing data from Signal and from MGS (see Figure 4): very low differences are found, therefore the following results will be all referred to MGS data.
Rw data from ISO 140 – 3, when not corrected with C and Ctr, are in good agreement with all data obtained from the real spectra for all the considered samples; nevertheless, if compared to data from ISO 140 – 3 corrected with C and Ctr, significant differences are found. Therefore the indexes C and Ctr seem not to be able to correct data for traffic noise in laboratory measurements; a more in-depht analysis will be nevertheless carried out, in order to investigate the influence of the transmission at low frequencies, where the reverberating rooms seem to have a not very correct behaviour.

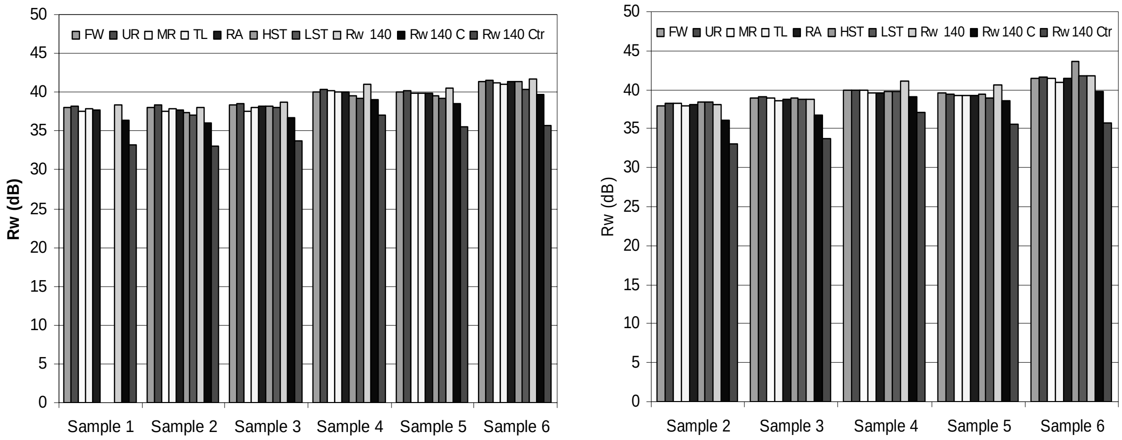

Figure 3: Rw evaluated with different spectra, with ISO 140-3 and corrected with C and Ctr for the different samples; A) Signal; B) MGS.

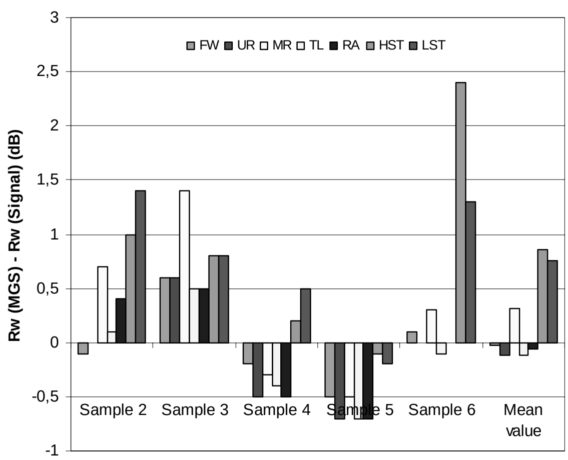

Figure 4: Difference between Rw (MGS) and Rw (Signal) for the different samples and the different traffic spectra.

An analysis of Level Abatements between emission and receiving room Le - Lr was also made (see Figure 5) both for Linear an A weighted levels; the maximum level abatements were found with HST for all the samples, while the minimum values were found with for RA or TL for all the samples. This is in agreement with noise spectra (see Figure 2); in fact HST is characterized by the lowest values of the level at low frequencies, while RA and TL have the highest values. Therefore it may be concluded that all the samples have better acoustic performances at high frequencies than at low frequencies. It could be seen also from the level abatements vs. frequencies for the different samples (Figure 6), from which a certain instability at low frequencies is also evident in all the samples. Windows show in fact a different behaviour at low frequencies with varying the noise spectrum: for HST spectrum the higher values of the abatements at low frequencies were found, while for the frequencies over 315 Hz the abatements seem not be influenced by the spectrum characteristics. A more in-depth analysis is nevertheless necessary.

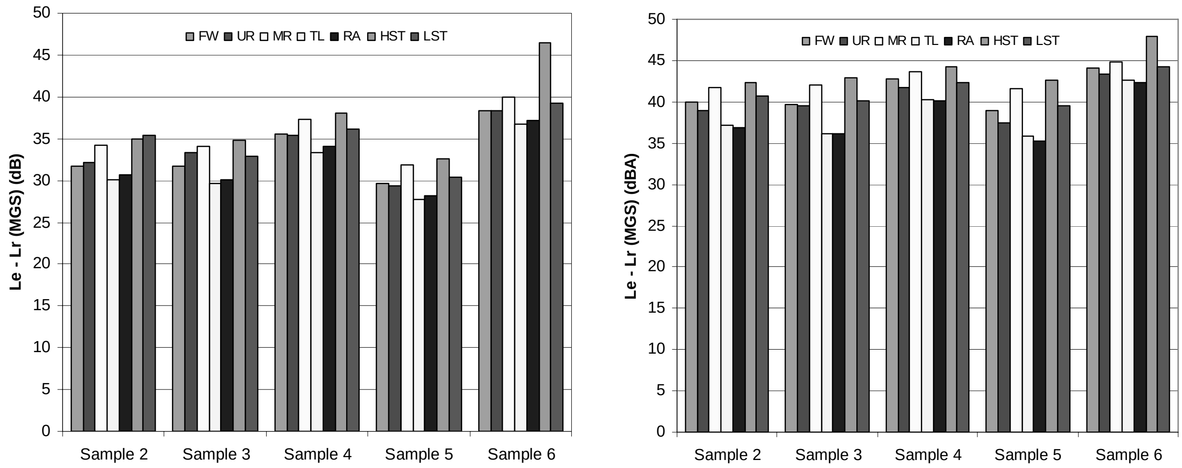

Figure 5: Abatement Le – Lr (MGS): A) Linear, B) A Weighted.

4. CONCLUSIONS

A wide experimental campaign was carried out at the Acoustics labs of the University of Perugia, in order to evaluate the influence of the traffic characteristics on the indoor noise transmitted by windows and to investigate the significance of the C and Ctr Indexes introduced by UNI EN ISO 717 – 1. Five different traffic noise spectra and two different train noise spectra were registered and reproduced into the reverberating rooms, simulating the outdoor conditions in the emission room and the indoor conditions in the receiving room; the rooms were separated by a wall with six different samples of windows. The Rw values, the Level Abatements and the spectra transmitted across the windows were measured.

Results obtained comparing Rw values obtained from the different spectra for each sample and Rw values from ISO 140 – 3 showed that Rw when corrected with C and Ctr, are not in good agreement with data obtained from the real spectra for all the considered samples; indexes C and Ctr seem therefore not to be able to correct data for traffic noise in laboratory measurements; a more in-depth analysis is nevertheless necessary, in order to investigate the influence of the transmission at low frequencies.

The maximum level abatements were found with HST for all the samples, while the minimum values were found with for RA or TL for all the samples, is in agreement with noise spectra

(HST has the lowest level values at low frequencies while RA and TL have the highest values); therefore it's possible to say all the samples have a better acoustic behaviour at high than at low frequencies.

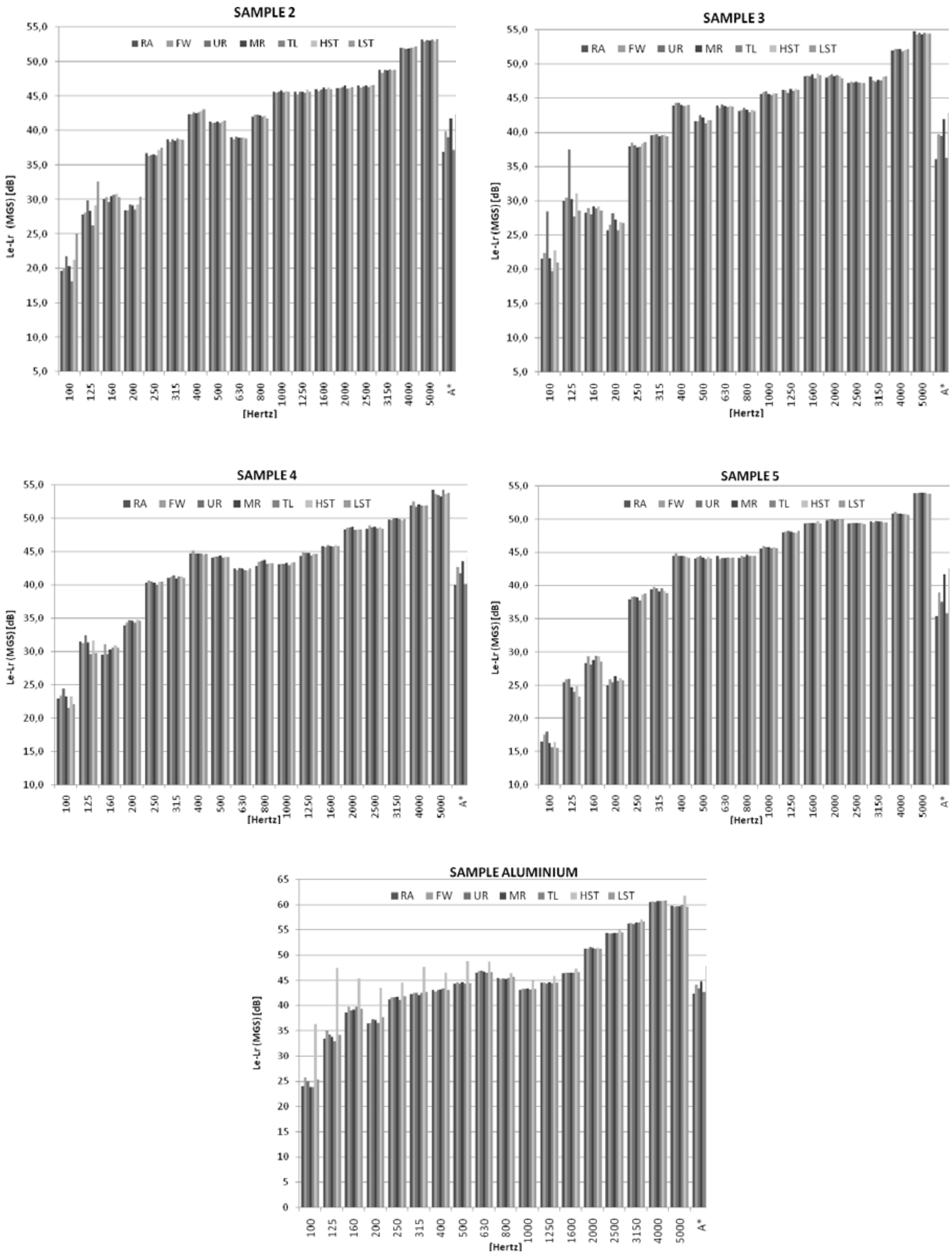

Figure 6: Comparison between the sound pressure level differences of different traffic noise for different windows.

ACKNOWLEDGMENTS

Authors wish to thank FAIL S.p.A. (Marsciano – PG, Italy) to have allowed measurements on their window samples and Elisa Belloni for her contribution in the measurements.

REFERENCES

[1] *UNI EN ISO 717-1*: "Acoustics. Rating of sound insulation in buildings and of building elements, Airborne Sound Insulation", (December 1997).

2*UNI EN ISO 140-3*: "Acoustics. Measurements of sound insulation in buildings and of building elements. Laboratory measurements of airborne sound insulation of building elements", (2006).

3*UNI EN 1793-3*: "Road traffic noise reducing devices. Test method for determining the acoustic performance - normalized traffic noise spectrum", (1999).

[4] Luciano Rocco, Carlo Baistrocchi , "Valutazione dei requisiti acustici degli edifici per la protezione dai rumori per via aerea con indici a singolo numero in dBA", *AIA – Italian Acoustics Association – 34° National Conference* (Firenze, 2007) (in Italian).

[5] Luciano Rocco, Carlo Baistrocchi, "Dipendenza dei termini di adattamento spettrale di cui alla UNI EN ISO 717-1 dalle tipologie costruttive e dalle caratteristiche fisiche di elementi edilizi", *AIA – Italian Acoustics Association – 35° National Conference* (Milano, 2008) (in Italian).

[6] Simone Secchi, Gianfranco Cellai, "Relazione tra prestazioni acustiche passive degli edifici e comfort acustico degli ambienti interni: La trasmissione dei rumori aerei", *Rivista italiana di acustica* (2008) (in Italian).

[7] Antonino Di Bella, "Le prestazioni acustiche degli elementi edilizi: la determinazione in laboratorio del potere fonoisolante",Università di Padova, Dipartimento di Fisica Tecnica (Settembre 2005) (in Italian).

[8] R. Spagnolo, *Manuale di Acustica*, (UTET Libreria, Torino, 2001) (in Italian).