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Traffic Noise Pollution: Spectra Characteristics and Windows Sound Insulation in Laboratory and Field Measurements

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Abstract: The traffic spectra influence on indoor noise through windows is evaluated with laboratory and field measurements. Different traffic noise spectra were registered and reproduced, simulating the outdoor traffic conditions through different windows. Spectrum adaptation terms for the recorded spectra were different from the ones obtained from the Standards, showing that Normative gives a safe evaluation of the Weighted Sound Insulation Index. In field measurements, the level abatements calculated from the Façade Acoustic Insulation Index corrected with the adaptation terms shows that the ones from the Standard do not give a good approximation, while if the level abatements is calculated using the adaptation terms from the registered spectra, a more reliable approximation is achieved. Furthermore, comparing the level abatements for two windows having both R_w equal to 41 dB, very different values were obtained at different frequencies; therefore to characterize acoustic performances of windows, sound insulation curves are also needed. The correlation between the mean difference between adaptation terms calculated from the standard and the one between abatements obtained with pink noise and the ones obtained with the registered spectra is good, but different for road traffic and trains. In both, the difference diminishes when the difference between the abatements increases.

Key words: Traffic noise pollution, traffic noise spectra, spectrum adaptation terms, level abatements.

Nomenclature

A = Abatement;
APN = Abatement with pink noise;
C = Spectrum adaptation term calculated with Spectrum n. 1 (UNI EN ISO 717–1) (dB);
C_i = Spectrum adaptation terms calculated with registered spectra (dB);
C_{tr} = Spectrum adaptation term calculated with Spectrum n. 2 (UNI EN ISO 717–1) (dB);
FW = Freeway (-);
HST = High Speed Train (-);
L = Pressure level (dB, dBA);
L_e = Pressure level in emission room (dB, dBA);
L_r = Pressure level in receiving room (dB, dBA);
LST = Low Speed Train (-);
MGS = Mean Generated Spectrum (-);
MR = Main Road (-);
R = Sound Insulation Index (dB);
RA = Roundabout (-);
R_w = Weighted Sound Insulation Index (dB);
TL = Traffic Lights;
UR = Urban Road.

1. Introduction

In recent years there has been a growing interest in noise pollution, especially in big urban areas, where is often impossible to reduce the noise at the sources or to insert noise barriers. In these cases it is necessary to take care of the building insulation. Although the design of a building now takes into account conditions of health including noise level, intervention is often needed in pre-existing situations, where the noise

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conditions are unacceptable such as near roads, railroads, airports and where the usual noise control techniques are not always sufficient [1-7]. Several prediction models were developed to evaluate the sound pressure levels and the annoyance caused by traffic noise [5-11]. In these cases, special measures are therefore necessary to reduce the sound pollution, such as installing high sound insulation windows [12]. Windows are in fact the weakest part of a façade from an acoustical point of view.

In the present paper a new approach to the noise transmitted through windows was considered. The aim was to verify the sound insulation behaviour of windows, when noise is generated by different traffic noise spectra registered in the field. The ISO 717 standard series [13] describes a method to obtain a single number characterizing the acoustic performances of partitions or building elements (such as R_w, R_w' and so on). Furthermore, two spectrum adaptation terms (C and C_{tr}) are given, in order to incorporate the influence of spectrum characteristics on the final value; the terms are a correction of the single number values. In particular, ISO 717-1 [13] uses two normalized spectra: n. 1 (for the calculation of C) representing living activities, high and medium speed train noise, motorways (speed>80 km/h), low distance reaction plains, factories with high and medium frequencies noise and n. 2 (for the calculation of C_{tr}) representing urban road traffic, low speed train noise, factories with low and medium frequencies noise, high distance reaction plains, disco music. But the two spectra are not always able to represent different traffic conditions, depending on the aerodynamics, rolling and engine noise contributions, the traffic composition [10], the different speeds of the vehicles both for road and railway traffic [3-4, 12] and the road or railroad characteristics, such as slope [9], kind of asphalt, rails, etc. [14].

The new approach of this study evaluates the influence of the traffic spectrum characteristics on the indoor spectrum transmitted across different windows, by means of laboratory and field measurements; they were carried out at the Laboratory of Acoustics of the University of Perugia, where two coupled reverberating rooms are available, wholly in compliance to UNI-EN ISO 140-1 [15], and in a typical terraced house. Different traffic noise spectra were registered outside and a comparison with spectra n° 1 and n° 2 (ISO 717-1) was carried out. The registered spectra were normalized in compliance with UNI EN ISO 140-1 and reproduced in the emission room or outside the terraced house, simulating the outdoor conditions. The indoor conditions (through six window samples installed on the wall between the rooms or inside the terraced house) were measured, in terms of level abatements and noise spectrum in the receiving room. Data obtained by the spectrum proposed by ISO 140-3 [16] and the reproduced spectra were compared, in order to evaluate the variations of spectrum adaptation terms by varying the noise source characteristics, with respect to C and C_{tr} obtained from Spectrum n. 1 and Spectrum n. 2, such as in ISO 717-1.

In the field measurements of the A weighted level abatements were measured and compared to the façade acoustic insulation index $D_{2m,nTw}$ measured with pink noise and corrected with C and C_{tr} from ISO 717-1.

A correlation between the variation of the level abatements and the C and C_{tr} adaptation terms with respect to the values obtained with the pink noise was finally calculated both for laboratory and field tests.

2. Material and Methods

2.1 Instrumentations and Noise Spectra

Different noise spectra were considered, in order to evaluate their influence on the noise transmitted through windows. The noise spectra were registered in the field, in different traffic conditions, both for road and railway traffic. Road traffic in fact generated very different noise spectra, depending on the road characteristics and on the vehicles rates, kind and speed. Train traffic also generated different spectra: in particular we can distinguish spectra for High Speed Trains and Local Trains.

Twelve road traffic noise spectra were registered in the city of Perugia and its surroundings: Freeway (FW1 and FW2), Urban Roads (UR1, UR2, UR3, UR4, UR5), Main Road (MR), Traffic Lights (TL1 and TL2) and Roundabout (RA1 and RA2). Two train noise spectra were furthermore registered: High Speed Train (HST) and Low Speed Train (LST).

Spectra were registered by the acquisition system dB-Steel SYMPHONIE. Spectra in 1/3 octave band were registered; data were elaborated by means of the following software: dBFA, dbBATI32, dBTRAIT32 and dBTRIG by 01dB-Stell. The road spectra were recorded for 30 minutes while the train spectra were recorded as the train passed. Fig. 1 shows the sampling procedure.

The characteristics of the traffic noise sources used in the present experimental campaign are reported in Table 1. The spectra obtained by the measurements and

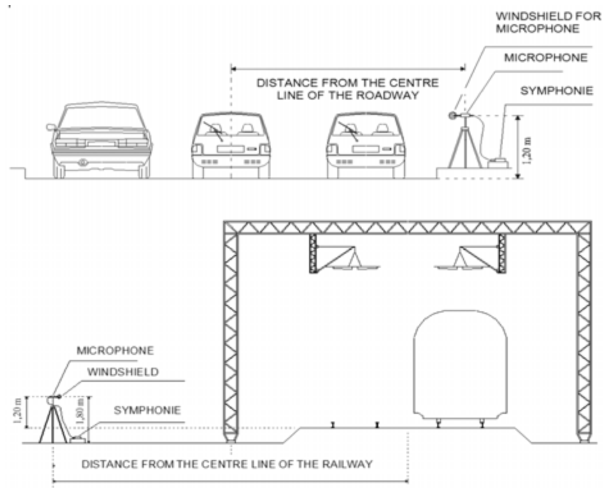

Fig. 1 Sampling procedure for traffic and train noise spectra.

Table 1 Characteristics of the traffic noise sources.

Noise source	Characteristics	Speed limit (km/h)	Traffic rate (vehicles/hour)
FW1	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)
FW2	Extra-urban Main Road, dual carriage way, each way two lanes, longitudinal slope 0%	110	3365 (91% Light vehicles, 8% heavy vehicles, 1% motor-cycles)
MR	Extra-urban Road, two lanes two-way, longitudinal slope 0%	90	780 (96% Light vehicles, 1% heavy vehicles, 3% motor-cycles)
UR1	Urban sliding road, three lanes one-way, longitudinal slope 5%, went along rising	50	2050 (95% Light vehicles, 2% heavy vehicles, 3% motor-cycles)
UR2	Urban sliding road, two lanes two-way, longitudinal slope 0%	50	1568 (93% Light vehicles, 3% heavy vehicles, 4% motor-cycles)
UR3	Urban sliding road, two lanes two-way, longitudinal slope 5%	50	1100 (92% Light vehicles, 7% heavy vehicles, 1% motor-cycles)
UR4	Urban sliding road, in the old town, one lane one– way, longitudinal slope 0%	50	280 (84% Light vehicles, 14% heavy vehicles, 2% motor-cycles)
UR5	Urban sliding road, two lanes two-way, longitudinal slope > 5%	50	1168 (97% Light vehicles, 2.5% heavy vehicles, 0.5% motor-cycles)
TL1	Traffic-lights with four branches	50	1154 (94% Light vehicles, 4.5% heavy vehicles, 1.5% motor-cycles)
TL2	Traffic-lights with three branches	50	820 (95% Light vehicles, 5% heavy vehicles, 0% motor-cycles)
RA1	Roundabout with four entrances	50	1970 (91% Light vehicles, 8% heavy vehicles, 1% motor-cycles)
RA2	Roundabout with three entrances	50	1192 (88% Light vehicles, 10% heavy vehicles, 2% motor-cycles)
HST	Straight railway, far from level crossings	100-250[a]	-
LST	Straight railway, far from level crossings	90-140[a]	-

[a] train speed.

normalized to 0 dB(A) are reported in Fig. 2, together with the spectra n. 1 and n. 2 proposed by UNI EN ISO 717-1 for the calculation of C and C_{tr} Indexes. Freeway, Main Roads and High Speed Train can be compared to Spectrum n. 1: the values are higher than the ones for our noise spectra in the low frequency range. Moreover, in the low frequency range all the spectra are different from the Spectrum n. 2: this one is more stringent than all the measured noise spectra.

Measurements on the windows were carried out at the reverberating rooms of the Acoustics Laboratory-University of Perugia. The rooms were built in compliance with ISO 140-1 and are described in some previous works [1, 2, 12]. In the emission room the above mentioned registered spectra were reproduced into two ways:

- as registered on the road (named Signal), using a representative time period for the real traffic noise (3 minutes, the same period for all the road noise spectra) while for trains the period of the train transit was chosen including approach and departure;
- after the construction of a mean spectrum by means of the software COOL EDIT PRO 2.0 (named Mean Generated Spectrum, MGS) for a period of 3 minutes (the same period for all the spectra, except for the train noise, for which only carriages transit was considered [17]). Cool Edit Pro is a digital audio editor computer programme from Adobe System featuring both a multi-track, non-destructive mix/edit environment and a destructive approach waveform editing view.

Laboratory 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. The instrumentation 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, were used to detect the acoustic signals.

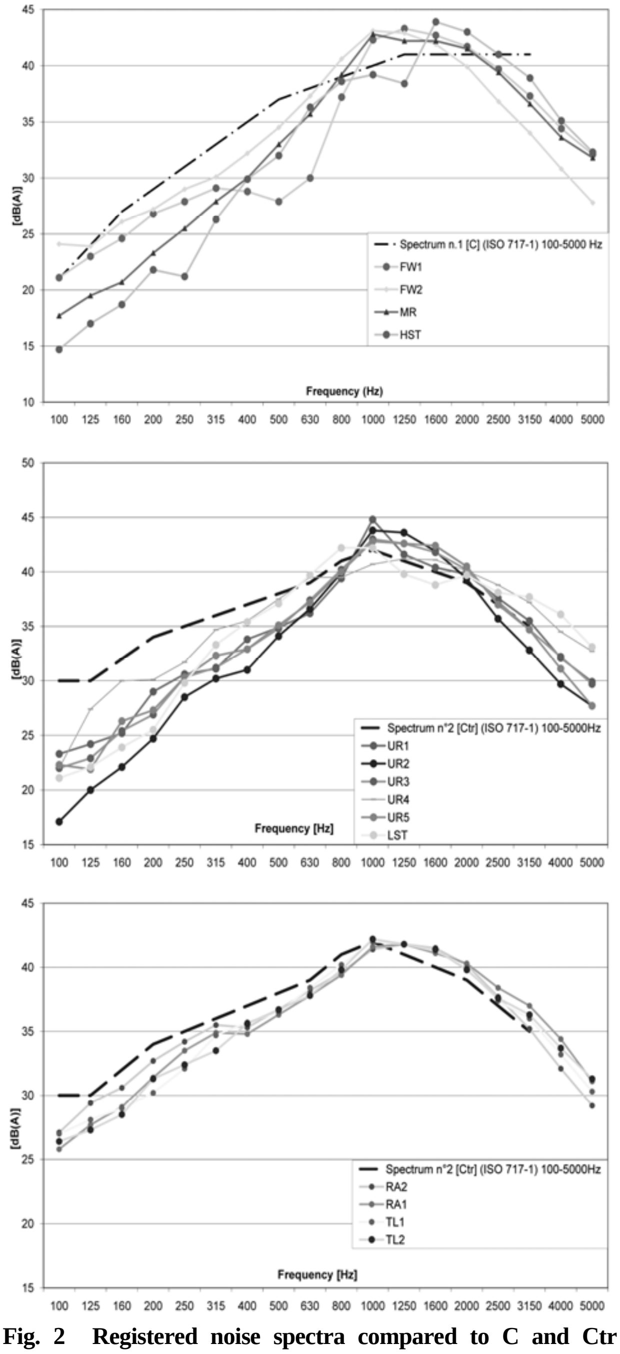

Fig. 2 Registered noise spectra compared to C and Ctr spectra (ISO 717-1).

The field measurement session took place in a typical terraced house: the sample room is situated at the first floor (total surface 15.2 m^2; façade surface 10 m^2) with one window. The test procedure follows the standard ISO 140-5 [18] to determine the façade acoustic insulation index $D_{2m,nTw}$. The inner room instrumentation is the same as used in the laboratory test while for the outdoor acquisition a directional noise source was used, produced by Montarbo, linked to a CD reader, and a sound level-meter 01 dB Steel Solo, with the microphone fixed on a tripod.

2.2 Windows Characteristics

In laboratory measurements six different samples of windows were investigated. They could be divided into three groups:

- wood frame, section 56×68 mm, with different glasses (samples 1 and 2);
- wood frame, section 68×78 mm, with different glasses (samples 3, 4 and 5);
- aluminum frame (sample 6).

All the samples have 1,220×1480 mm dimensions (external frame), for a total area of 1.82 m^2. The windows are characterized by different type of glass, with glass R_w values in the 38-41 dB range. The characteristics of the windows are reported in Table 2.

They were installed in the wall between the two rooms, built with two layers of insulating concrete blocks, for a total thickness of 420 mm including plastering. The window in the field test is a wood frame one with double glass (total surface 1.96 m^2).

3. Results and Discussion

3.1 R_w and $D_{2m,nTw}$ Calculations

R_w values measured in the reverberating rooms in compliance with ISO 140-3 both with pink noise and the registered spectra are in the 38-41 dB range: very low differences (-0.5÷ + 2.5 dB) were found employing Signal and Mean Generated Spectrum (MGS). Furthermore, R_w data from ISO 140-3 are in agreement with all data obtained from the real spectra for all the samples considered: a correct evaluation of R_w could also be made with noise spectra different from white or pink noise.

The façade acoustic insulation index $D_{2m,nTw}$ for the field measurements was 38 dB with pink noise and 39 dB with MGS.

3.2 Spectrum Adaptation Terms C_j

In UNI EN ISO 717-1 the terms C and C_{tr} were introduced to take into account different noise spectra; UNI EN ISO 717-1 also says that in many countries, where traffic noise is used as the noise source, the obtained R_w value could be used instead of the value corrected with C_{tr}.

C_i values calculated for the different registered spectra in the laboratory tests are reported in Table 3.

Generally, the lowest C_i are obtained for low pitched noise spectra, like traffic lights and roundabout, while the highest values are generally due to high pitched noise, like the HST, such as in Refs. [19]. Furthermore, the lowest values of C_i correspond to spectra where the dominant values lie in the frequency range in which the sound insulation is poorest, such as in Ref. [19] for spectra generated from musical instruments. For all the windows the low frequencies are the ones where the

Table 2 Characteristics of the investigated windows.

Sample	Characteristics	Glass (mm)	Rw (dB) (C; Ctr)	Rw* (dB)
1	Wood (pine heartwood) frame, with mobile shutters, section 56×68 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 56×68 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 68×78 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 68×78 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 68×78 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 62×74 mm, rounded contours with double rabbet and acoustic gasket.	66.2a-90% Argon 20-44.2 low-e	41 (0;-5)	41.7

*not rounded value.

Table 3 Laboratory tests: Adaptation Spectrum Terms C_i calculated for the registered spectra and C and C_{tr} calculated for Spectrum n. 1 and Spectrum n. 2 from ISO 717-1.

Sample R_w	1 (38 dB)	2 (38 dB)	3 (38 dB)	4 (41 dB)	5 (40 dB)	6 (41 dB)	Mean value
FW1	0	0	0	-1	0	-1	-0.3
FW2	-1	-1	-1	-2	-1	-2	-1.3
UR1	-1	-2	-2	-2	-2	-2	-1.8
UR2	0	0	0	-1	0	-1	-0.3
UR3	-1	-1	-1	-2	-1	-2	-1.3
UR4	-3	-3	-2	-2	-3	-2	-2.5
UR5	-1	-1	-1	-2	-1	-2	-1.3
MR	0	0	1	-1	1	-1	0
TL1	-3	-3	-3	-3	-3	-3	-3
TL2	-3	-3	-3	-3	-3	-3	-3
RA1	-3	-3	-3	-3	-3	-3	-3
RA2	-4	-4	-4	-3	-4	-1	-3.3
HST	1	1	1	0	1	1	0.8
LST	-1	-2	-1	-2	-1	-1	-1.3
C	-2	-2	-2	-2	-2	-1	-1.8
C_{tr}	-5	-5	-5	-4	-5	-5	-4.8

Sound Insulation Index R is lower. With reference to the registered spectra (Fig. 2), for C_i we have:

- the lowest mean values (-3 ÷-3.3 dB) for TL1, TL2, RA1 and RA2, which have the highest levels at low
- frequencies; UR4, which is an urban road but with a spectrum similar to traffic lights and roundabouts (Fig. 2) due to the very low speed, has a value of -2.5 dB;
- intermediate mean values, from -1.8 dB to -1.3 dB, for all urban roads except UR4 (see point a)) and UR2 (see point c)), for LST and FW2, which have, in the order, lower levels than traffic lights and roundabouts at low frequencies;
- higher mean values,-0.3 dB to 0 dB, for FW1, MR, and UR2 which have lower levels, at low frequencies, than urban roads and LST; UR2 has a spectrum similar to the one of main roads and freeway, due to the high speed (Fig. 2);
- the highest mean value 0.8 for HST, which has the lowest levels at low frequencies.

A comparison between C_i and C or C_{tr} was also carried out. Table 4 shows the mean difference between C or C_{tr} evaluated by means of ISO 717-1 and C_i evaluated from the measured spectra for laboratory tests. The adaptation terms for the registered spectra are always lower and therefore less restrictive than those introduced by UNI EN 171-1, so the Norm allows a safe evaluation of the acoustic performances of windows. Furthermore, when corrected with C or C_{tr}, the values of R_w seem to be:

Table 4 Differences between C and C_{tr} calculated from ISO 717-1 and C_i calculated from the registered spectra.

Spectrum	Mean Difference between C or C_{tr} from ISO 717-1 and measured spectra
FW1 C	-0.5
FW2 C	-1.5
UR1 C_{tr}	-3.0
UR2 C_{tr}	-4.5
UR3 C_{tr}	-3.5
UR4 C_{tr}	-2.3
UR5 C_{tr}	-3.5
MR C_{tr}	-4.8
MR C	-0.8
TL1 C_{tr}	-1.8
TL2 C_{tr}	-1.8
RA1 C_{tr}	-1.8
RA2 C_{tr}	-1.5
HST C	-1.7
LST C_{tr}	-3.5

- well approximated if related to freeways or to main roads (the last if compared to C);
- underestimated by about 2 dB if related to traffic lights, roundabouts or HST;
- very underestimated (about 3-4.5 dB) if related to urban roads or LST and to main roads (the last about 5 dB, if compared to C_{tr}).

In field measurements C and C_{tr} values calculated with Spectrum n.1 and n. 2 from ISO 717-1 were -3.6 dB and -6.6 dB, while the values calculated with the registered spectra were in the -0.5÷-1.7 dB range (mean value -1.1 dB) for C and in the -4.8÷-1.5 dB range (mean value -2.9 dB) for C_{tr} [20].

3.3 Abatements

Windows show different behaviour at low frequencies with varying 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 to be influenced by the spectrum characteristics. With reference to noise spectra, the maximum level abatements were found with HST for all the samples, while the minimum values were found for RA1 or TL1 for all the samples (see Fig. 3). This is in agreement with noise spectra (see Fig. 2): HST is characterized by the lowest values of the level at low frequencies, while RA1 and TL1 have the highest values and all the samples have better acoustic performances at high frequencies if compared to low frequencies. Nevertheless if two samples with the same value of Rw (such as samples 4 and 6) are compared in terms of A weighted level abatements between emission and receiving room L_e-L_r, significant differences are found for all the registered spectra (Fig. 4), especially for HST (about 4 dB(A)) and TL1 and RA1 (more than 2 dB(A)).

The highest level abatements were found for sample 6; in fact it has a better acoustic behavior both at high (2000-5000 Hz) and at low (125-250 Hz) frequencies. Therefore, the weighted sound insulation index Rw seems not to be very reliable to characterize the acoustic performances of windows, but sound insulation curves are also needed.

In field measurements, the level abatements could be calculated from the values of $D_{2m,nTw}$ corrected with C and C_{tr}. The comparison between the abatements calculated in such a way and the measured abatements for the different traffic spectra (Table 5) shows that the Adaptation Terms Index C and C_{tr} do not give an accurate approximation, with very high differences (in the -4.8÷-2.6 dB(A) range). The abatements, if calculated considering C_{tr} from the mean normalized spectra for homogeneous groups, give differences in the range -0.7÷-1.4 dB(A), with a more reliable approximation.

A correlation between the mean difference between C or C_{tr} and C_i and the mean difference between abatements obtained with pink noise and the ones obtained with the registered spectra was finally evaluated, such as in Ref. [19], both for laboratory and field measurements; for laboratory tests mean data for the six

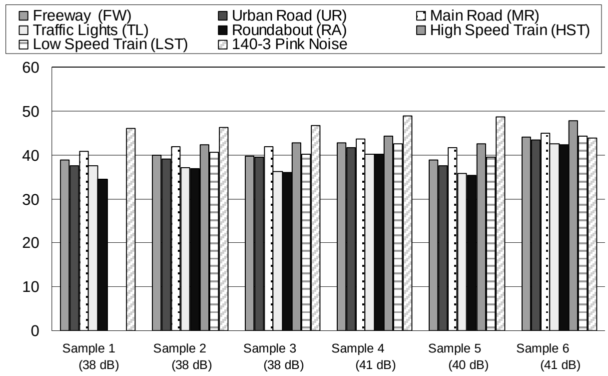

Fig. 3 Abatements L_e-L_r for the different windows and the examined spectra.

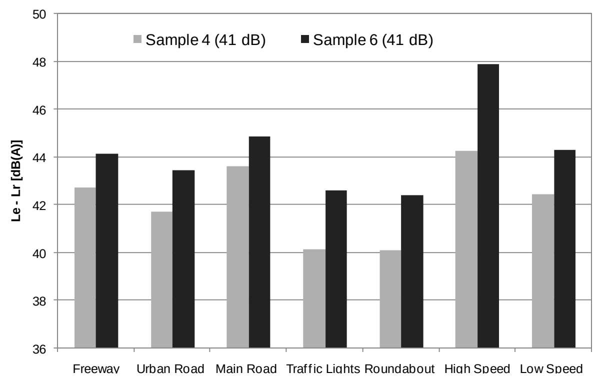

Fig. 4 Level abatements L_e-L_r (dB(A)) for the different spectra, for samples 4 and 6 (same value of R_w, equal to 41 dB).

Table 5 Differences between calculated and measured abatements linked to C, C_{tr} and C_{tr2}.

	Abatements (dBA)	$D_{2m,nTw}$ + C or C_{tr}	Differences	Mean differences	$D_{2m,nTw}+C_{tr2}$	Differences	Mean differences
FW	39.4	36.8	-2.6	-2.7	38.8	-0.6	-0.7
FW2	39.4	36.8	-2.6			-0.6	
MR	39.8	33.8	-3.0			-1.0	
UR1	38.2	33.8	-4.4	-4.4	36.8	-1.4	-1.4
UR2	38.6	33.8	-4.8			-1.8	
UR3	38.4	33.8	-4.6			-1.6	
UR4	37.4	33.8	-3.6			-0.6	
UR5	38.3	33.8	-4.5			-1.5	
RA	37.2	33.8	-3.4	-3.3	35.8	-1.4	-1.3
RA2	36.4	33.8	-2.6			-0.6	
TL	37.2	33.8	-3.4			-1.4	
TL2	37.3	33.8	-3.5			-1.5	
UR4	37.4	33.8	-3.6			-1.6	
HST	41.1	36.8	-4.3	-	-	-	-
LST	38.6	33.8	-4.8	-	-	-	-

windows were considered and referred to the spectra of the first experimental campaign (FW1, UR1, MR, RA1, TL1, HST, LST), for which the abate- ments were available. All the results are shown in Fig. 5, where the difference C_{tri}-C_{tr} (or C_i-C) diminishes when the difference between the abatements A–APN increases. A good correlation was found (y=-0.551x + 2.428; R^2=0.899). Furthermore, two groups of data could be considered: field data, for which a positive variation of the Spectrum Adaptation Terms is obtained if the corresponding difference in abatements is negative; laboratory tests, for which a negative variation of the Spectrum Adaptation Terms is obtained if the corresponding difference in abatements is positive. Results in Fig. 5 are obtained excluding data related to train spectra both in field and in laboratory tests; they also give a linear but different correlation (y=-1.164x-4.336; R^2= 0.920) and in this case both differences (Spectrum Adaptation Terms and Abatements) are negative.

4. Conclusions

A wide ranging set of experiments was carried out at the Acoustics Labs of the University of Perugia and in field, in order to evaluate the influence of the traffic characteristics on the indoor noise transmitted through windows and to investigate the significance of the C and C_{tr} Indexes introduced by UNI EN ISO 717-1. Twelve different traffic noise spectra and two different train noise spectra were registered and reproduced in the reverberating rooms, simulating the

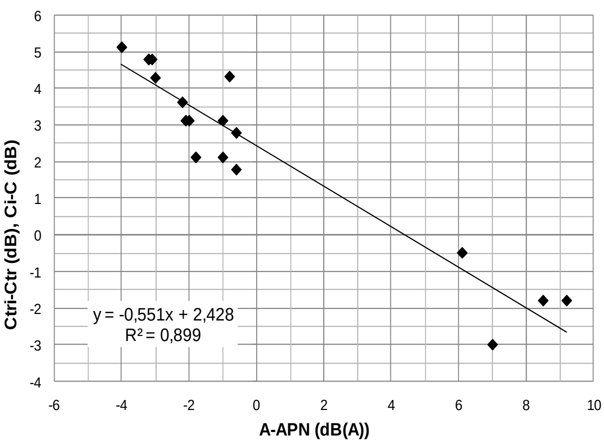

Fig. 5 Mean difference between C_i and C or C_{tr} vs. mean difference between abatements with registered spectra and abatements with pink noise.

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. Field measurements were also carried out in a typical terraced house.

The following parameters were measured:

- weighted Sound Insulation Index R_w with pink noise and registered spectra in the laboratory tests;
- C, C_{tr} and C_i spectrum adaptation terms related respectively to spectrum n. 1 and spectrum n. 2 from ISO 717-1 and to the fourteen registered spectra;
- linear and A weighted Level Abatements;
- spectra transmitted through the windows;
- façade acoustic insulation index $D_{2m,nTw}$ in the field tests.

Results obtained comparing the Weighted Sound Insulation Index R_w from the different spectra for each sample and R_w values from ISO 140-3 showed R_w seems to be not very reliable to characterize the acoustic performances of windows, because if the level abatements of windows with the same R_w are compared, significant differences are found, therefore sound insulation curves are also needed.

Data obtained for the spectrum adaptation terms for the registered spectra C_i are always lower if compared to C and C_{tr} evaluated from Spectrum n. 1 and n. 2 from ISO 717-1; therefore the Norm underestimates the acoustic performances of windows, allowing a safe evaluation when R_w data corrected with C or C_{tr} are used instead of R_w, such as in some countries. Differences from 0 to 5 dB(A) could be found.

The maximum level abatements were found with HST for all the samples, while the minimum values were found for roundabouts or traffic lights both in laboratory and in field tests. It is in agreement with noise spectra (HST has the lowest level values at low frequencies while roundabouts and traffic lights have the highest values) and with the better acoustic behaviour of all the samples at high compared to low frequencies.

In field measurements, the level abatements calculated from the values of $D_{2m,nTw}$ corrected with C and C_{tr} shows that the Adaptation Terms Index C and C_{tr} do not give an accurate approximation, while the abatements, if calculated considering C_{tr} from the registered spectra, give a more reliable approximation.

Finally, a correlation between the mean difference between C or C_{tr} and C_i and the mean difference between abatements obtained with pink noise and the ones obtained with the registered spectra was evaluated. Good correlations were found, but different for road traffic and trains. In both the difference C_{tri}-C_{tr} (or C_i-C) diminishes when the difference between the abatements A-APN increases.

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