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SOUND INSULATION PERFORMANCES OF WINDOWS: EVALUATION OF THE INFLUENCE OF DIFFERENT TRAFFIC NOISE SPECTRA IN LABORATORY AND FIELD MEASUREMENT

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The influence of the traffic spectra characteristics on the indoor noise transmitted by windows is evaluated by means of in the field measurements. Fourteen different traffic noise spectra are registered, choosing different situations of traffic speed and intensity conditions, both for vehicles and trains. Spectra are reproduced outside a typical residential building: the measurement methodology is the same of the one given by the standard 140-5, but further than the classic pink or white noise all the fourteen spectra are tested. The A weighted levels abatements depend strictly on the different kind of spectra with no changeability of the window performances. Moreover, the paper contains a comparison between the spectrum adaptation terms C and C_{tr} given by the standard ISO 717-1 to correct the façade insulation index.

1. Introduction

The design of a building could not ignore the good insulation properties of walls and windows to guarantee indoor conditions of ‘‘well-being’’ noise level. Particularly, a correct design procedure is requested in urban areas, where buildings are often nearby to strong noise sources such as roads, railroads or airports. Even if the international standards give a detailed procedure to evaluate and to measure sound pressure levels and the annoyance from traffic noise, the field situation are often extremely various.

The sound insulation of windows, which are the weakest part of a façade, is a fundamental instrument for the acoustic designer. The sound insulation behaviour of windows in laboratory and in the field measurement is normally carried out in compliance to the international standard by a pink or white source noise and the ISO 717-1 standard series [1, 2] give two spectrum adaptation terms (C and C_{tr}) to consider the influence of spectrum characteristics on the final value. The function of these two terms is to correct the single number values by means of 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; 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.

The present paper describes the methodology and the results of a in field measurement session to verify the insulation of windows by using not just the pink noise but real signals previously registered and processed. A comparison between the C or C_{tr} spectra and the experimental ones leads to some considerations about the spectrum influence. The A weighted level abatements between emission and receiving rooms (or outdoor and indoor in field measurements) are calculated and compared for the different traffic spectra. Finally, a correlation between the variation of the level abatements, the correction with C and C_{tr} adaptation terms and façade acoustic insulation index referred to the fourteen traffic conditions is suggested, to obtain better performances during the design decision.

2. Methodology

2.1 Noise sources, spectra acquisition and data processing.

The fourteen noise spectra were registered in the city of Perugia and its surroundings, in different traffic conditions, both for road and railway. The spectra are deeply different depending on the road characteristics, vehicles rate and type and on the speed, such as for the train traffic. Table 1 shows all the main features of the above mentioned traffic noise sources and also the subdivision in light or heavy vehicles and motorcycles.

The acquisition system was the 01 dB-Steel Symphonie, with 1/3 octave band spectra; data were elaborated by means of the software package of the instrument. The road spectra were recorded for 30 minutes while the train spectra were recorded as the train passed. The spectra were normalized to 0 dB(A) [3], as shown in Fig. 1 and Fig. 2, collected in order to obtain a right comparison with spectrum adaptation terms C and C_{tr}, according to the standard ISO 717-1.

The registered spectra were processed in order to obtain a sample of the signal and than reversed on a cd; then it was created a Mean Generated Spectrum (MGS) using the software COOL EDIT PRO 2.0: the spectra last 3 minutes (the same period for all of them, except for the trains which are shorter, including just the train pass).

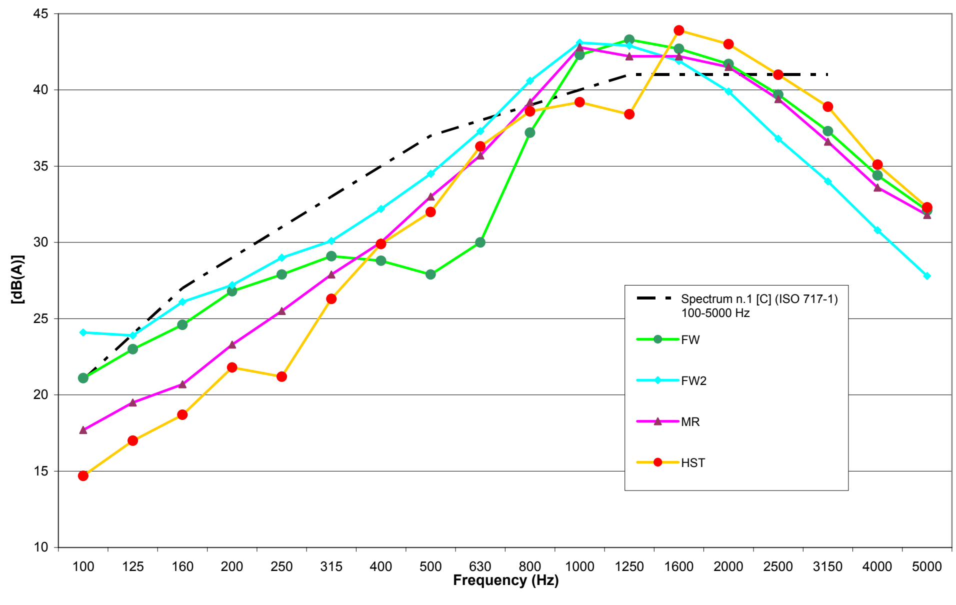
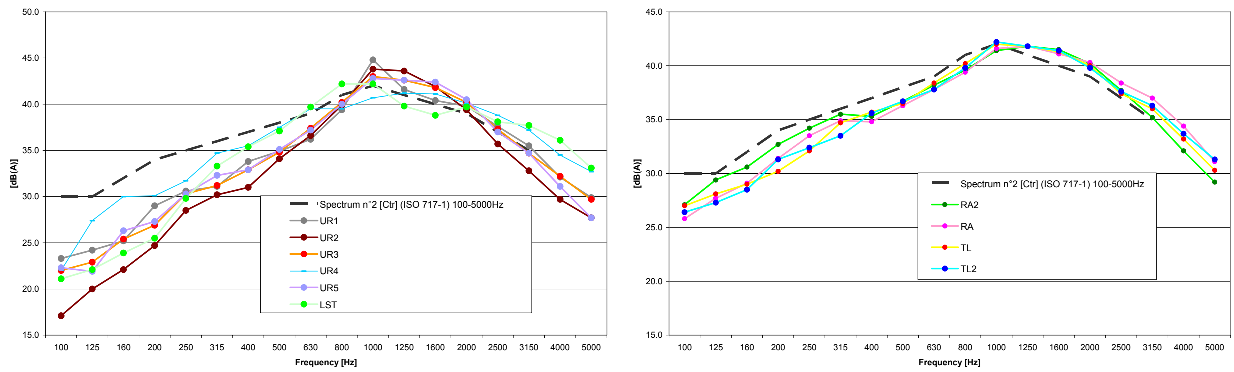


Figure 1: Registered noise spectra compared to C spectra (ISO 717-1).



a) b)

Figure 2: a) UR and LST, b) registered noise spectra compared to C_{tr} spectra (ISO 717-1).

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

*train speed

2.2 Laboratory measurement sessions

Measurements on the windows were carried out, in a previous experimental campaign, at the reverberating rooms of the Acoustics Laboratory – University of Perugia; the rooms were built in compliance to ISO 140-1 [4] and are described in some previous works [5, 6, 7]. Laboratory measurements were carried out using the Symphonie system, which consists of two transducers connected to a small acquisition unit linked directly to a notebook. The instrumentations also consists of an omnidirectional 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.

2.3 Field measurement sessions

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, wood frame with double glass (total surface 1,96 m^2). The test procedure follows the standard ISO 140-5 [8] to determine the façade acoustic insulation index $D_{2m,nTw}$.

The inner room instrumentation is the same described in the previous subsection while for the outdoor acquisition it was used a directional noise source produced by Montarbo, linked to a CD reader and a sound level-meter 01 dB Steel Solo, with the microphone fixed on a tripod (see Figure 3).

Figure 3: Field measurement session; outdoor and indoor view

Using the classic pink noise it was obtained the façade acoustic insulation index; after that, the measurements were repeated using the registered spectra both MSG and signal, to obtain the abatements and the façade acoustic insulation index $D_{2m,nTw}$. The value of this index both for the pink noise and for the MSG got a very small difference (Pink Noise $D_{2m,nTw}$=38 dB; MSG $D_{2m,nTw}$=39 dB).

3. Results and discussion

This section contains the results' discussion: the first one is dedicated to the calculation of the spectrum adaptation terms carried out using data got in the laboratory measurement session, the second one is dedicated to the field measurement session outputs.

3.1 Adaptation terms C and C_{tr} for the measured spectrum

Six different samples of windows were investigated in the reverberation rooms [7, 9]; they have different features like size and material frame, type of glass and the R_w values are in the range 38 – 41 dB.

It was carried out a mean value of the Adaptation terms Indexes for each spectrum and for each sample; then, the difference between the last output and the values of C and C_{tr} given by the pink noise measurement session was calculated; values are quite similar, with light differences

(Figure 4), if considering noise sources with similar spectra (urban roads, roundabout and traffic-lights, high speed roads).

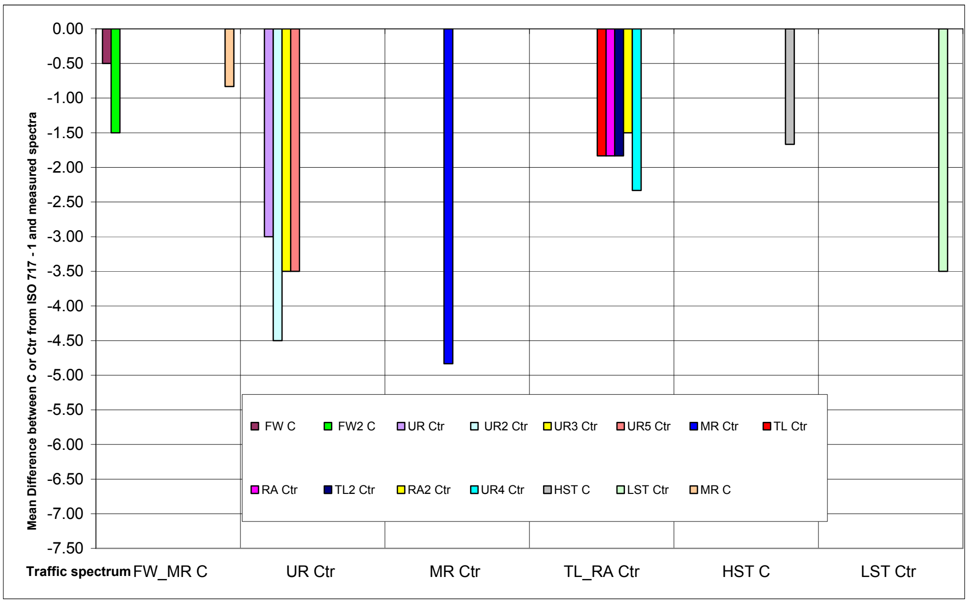


Figure 4: Mean differences between C and C_{tr} calculated from ISO 717 – 1 and from the registered spectra

3.2 In the field measurements

During the field measurements, the façade acoustic insulation index was obtained with the pink noise. After the post processing procedure in compliance to ISO 717-1, a $D_{2m,nTw}$ = 38,8 dB was found, with C = -2, Ctr =-5.

Moreover, the following equations describes the relationship to determine the abatements [10]:

$$L_{1,2m,A} - L_2 = D_{2m,nTw} + C\ [dB(A)]. \quad (1)$$

$$L_{1,2m,A} - L_2 = D_{2m,nTw} + C_{tr}[dB(A)]. \quad (2)$$

The highest abatements were registered for all the spectra with heavy level at medium and high frequencies (Figure 5): HST, MR and FW. This is a typical behaviour of the windows given by the synergy of glass and frame. On the other hand, where the traffic noise is produced by vehicles at low speed, the main source are due to rolling and engine noise contributions and not to aerodynamics components: in these cases the abatements give low values such as for Round About and Traffic Lights. Moreover, the UR4, that represents a typical situation of the old town where the vehicles pass with speed lower than 50 km/h [11, 12], the abatement is similar to the ones given by RA and TL instead of other Urban Roads.

Furthermore, another correlation between the façade acoustic insulation index and the frequency distribution of the abatements for the fourteen spectra was searched. For the sake of brevity, Figure 6 shows the analysis for UR3: it's clear the agreement between the two trend lines. Particularly it could be noticed the poor performance at 250 Hz and 1250 Hz: the first one is linked to resonance frequency of the glass, the second one represents a powerless sound insulation property of the façade.

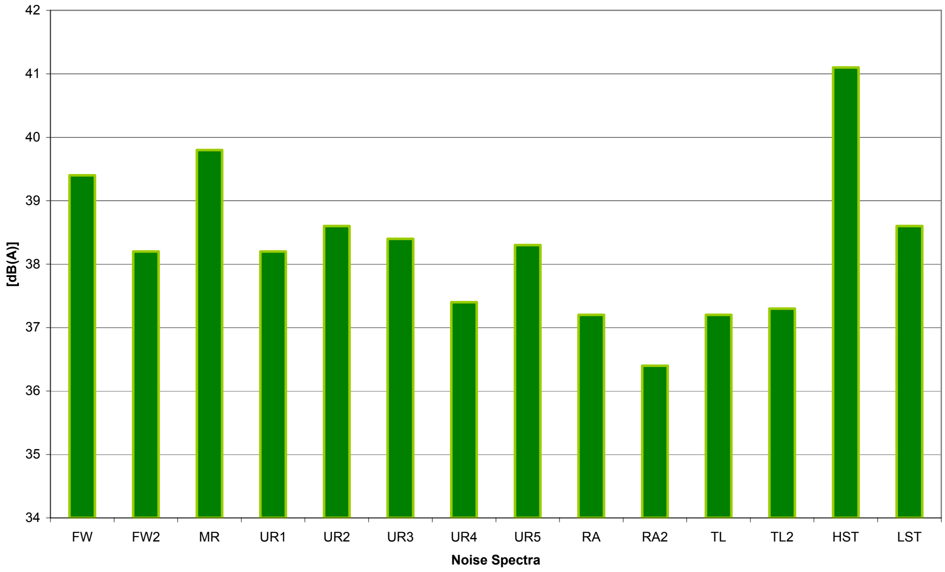


Figure 5: Mean abatements obtained in field measurement session for the MSG spectra

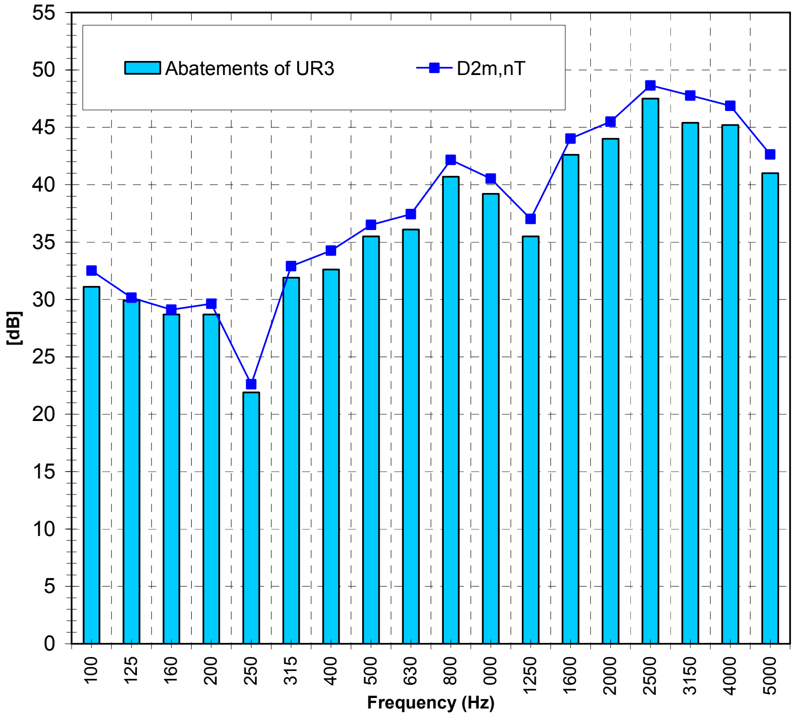


Figure 6: Abatements of UR3 versus façade acoustic insulation $D_{2m, nT}$

The frequency trend analysis of the façade acoustic insulation index shows poor values until 400-500 Hz: the smallest abatements overlap the signal unbalanced at the low frequencies.

Finally, a comparison between the abatements calculated with equations (1) and (2) and the measured abatements for the different traffic spectra was carried out (Table 2). The Adaptation Terms Index C and C_{tr} give a not sharp approximation with very high differences; results show that the measured abatements are higher than the calculated ones: the differences are contained in -4.8÷-2.6 dB(A) range. Therefore, the Adaptation Terms Indexes suggested by the ISO 717-1 underestimate the abatements above all for the UR, TL and for trains.

At the end, a medium value for C_{tr2} was calculated considering the mean normalized spectra for three groups: the first one contains FW, FW2 and MR, the second one TL, RA and UR4 and the last one the five spectra of Urban Roads. A mean value of the difference of -0.7 was found for the first group (-2.7 if evaluated with spectra n.1 or 2 from ISO 717), a value of -1.4 for the second group (instead of -4.4), a value of -1.3 for the third group (instead of -3.3).

Table 2: 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	-	-	-	-

4. Conclusions

The main results of the present study showed that the Adaption Terms Index given by the ISO 717-1, if compared to the registered fourteen spectra, give uniform results for the same traffic type in laboratory test for various windows sample; on the other hand, the results are extremely different for in field measurements.

The façade acoustic insulation index obtained with the classic pink noise was corrected with the adaptation term indexes C and C_{tr}, based on the traffic noise spectra; a comparison with the abatement levels shows that C and C_{tr} underestimate abatements especially for urban roads and for those spectra unbalanced at the low frequencies (e.g., Traffic Light, Round About or Urban Road with low speed); in all these cases, the correction does not work in a complete and right way. It would be more useful introducing a new adaptation term, called C_{tr2}, which could substitute the other ones in similar noise conditions and create a new list of correction terms. In fact, starting from these results, seems that the Adaptation Terms Indexes given by the ISO 717-1 underestimate the abatements in the calculation of the Acoustic Insulation Index. The abatements, if compared to data corrected with C_{tr2} (calculated for different groups of similar spectra), are in a good agreement, especially for roads with high speed (-0.7 dB(A)). The spectra of Ur and the ones unbalanced at low frequencies (which are very different, although of the same kind) could be improved collecting a more numerous sample, in order to have a more representative mean spectrum. Nevertheless they give a more reliable evaluation (-1.3 ÷ -1.4 dB(A)) if compared to spectrum n.1 and n. 2 given by ISO 717-1.

A solution could be study one or more new normalized spectra that could be representative for those situations in which the vehicles got low speed transit: it could be useful create some new categories which have some spectra that fit for speed lower than 50 km/h and in the range of 50-80 km/h.

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