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Façade noise abatement prediction: New spectrum adaptation terms measured in field in different road and railway traffic conditions

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ABSTRACT

The Façade Acoustic Insulation Index is one of the most disputed parameters for residential and non-residential buildings. The real performance of the façades does not often agree with the calculated one during the design stage. The field measurement sessions are usually carried out using pink noise spectra, as suggested by the International Standards ISO 717-1. In the present paper six mean spectra derived from in field measurements were proposed: urban toads, traffic lights, roundabouts, freeways, Highways, very high speed trains, high speed trains, and low speed trains. The proposed spectra were equalized against acoustic distortion and were used to measure the noise abatements in a terraced house and in a classroom façade. The highest abatements result for spectra with high levels at high frequencies, better absorbed than low ones by façade elements and frames. The spectrum adaptation terms were also calculated both for the standard and the proposed spectra and were used to predict the façade abatements in compliance with EN ISO 12354-3: the values C_j calculated from the proposed spectra provided more reliable results than the terms C and C_{tr} (ISO 717-1) and represent a useful tool to predict the noise façade abatements.

1. Introduction

In the recent years a great interest has focused on noise pollution, especially in urban areas, characterized by both high people and traffic density. It generally causes people annoyance, due to the indoor high noise levels generated by road and railway traffic. Road traffic is one of the main noise sources and it is characterized by very different acoustic spectra, related to road kind, number of vehicles per hour, typology of the vehicles and speed. Railway traffic is more non-continuous than road one and it also generates different spectra, essentially due to the train speed. In this context, building design in terms of noise insulation characteristics is very important because it is responsible for the noise abatements. It is also related to the characteristics of the spectra, outdoor emitted by different sources (road or railway traffic).

Different models are proposed in the Literature to predict traffic noise levels [1]. The early ones, developed in the 1950s and 1960s [2,3], predicted a single vehicle sound pressure level, while later models calculated the equivalent continuous level for traffic in a defined period, both for linear and A-weighted values [4–14]. More recent models allow also to predict one-third octave band spectra [15]. Several Authors developed traffic noise models based on experimental data in different areas worldwide and verified the reliability of the results by comparing them with the registered noise levels [16–19].

The characteristics of the spectrum are very important when it is used to evaluate the façade noise abatement, which strongly influences the indoor sound level and the occupants' annoyance [20–22].

Noise insulation characteristics of building façades are indeed strong frequency-dependent and their behavior is very different when the incident spectrum has a different distribution of the levels with frequency, even if the noise equivalent continuous level has the same value [23–25]. The current descriptors [26] used for the evaluation of airborne sound insulation of building façades are defined in ISO 717 [27], referring to measurements carried out according to ISO 140 [28] or estimated values by means of technical standards [29]. Single-number quantities are so calculated by comparison between 1/3 octave values (measured in laboratory and in field or estimated values) and reference curves. Then, in order to take into account different types of noise spectra, two spectrum adaptation terms (C, C_{tr}) are also introduced: they could be added to the single-number indexes in order to correct the obtained values, considering the frequency depending values and the reference spectra [30]. They have usually negative values, therefore they affect the insulation performance index: in some countries the limit values take into account the corrections provided by the adaptation terms [26]. Nevertheless, the International Standard ISO 717-1 [27] only proposes two Spectra (named N. 1 and N. 2) which represent all the possible road and railway traffic

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Nomenclature

C	spectrum adaptation term for spectrum N. 1 (ISO 717-1)
C_j	spectrum adaptation terms for the proposed spectra
C_{tr}	spectrum adaptation term for spectrum N. 2 (ISO 717-1)
D	diesel train
$D_{2mnT,w}$	façade insulation index normalized to the reverberation time (ISO 140-5)
FW	freeway
FR	"Frecciarossa" train
HST	high speed train
HW	highway
$L_{1,2m}$	outdoor sound pressure level measured at 2 m from the façade
L_2	pressure level measured in the receiving room
LST	low speed train
RA	roundabout
R_w	façade acoustic insulation index
SB	Symphonie measurement device
SY	Soundbook measurement device
TL	traffic light
UR	urban road
ΔL	measured noise abatement through the façade

conditions: Spectrum N. 1 is used for high speed road and railway traffic, Spectrum N. 2 for low speed road and railway traffic.

A different approach was therefore followed in the present paper, in order to consider the real traffic noise spectra and their influence on the façade level abatements. It is based on the registration of a wide number of different spectra both for road and railway traffic, aiming to obtain standard reference spectra representative of the possible traffic conditions in the modern urban and non-urban areas [31–33]. A similar approach was found in the Literature for the noise source spectra related to musical instruments [34].

A wider selection of traffic noise spectra is proposed in the present paper: 6 different mean spectra, obtained by 47 spectra in field registered, are used to predict the façade noise abatement. In this way the influence of the real characteristics of the spectra on the façade noise abatement should be evaluated and new proposed spectra should be useful in the ISO standards revision.

2. Methodology

In order to evaluate the influence of the characteristics of the registered spectra on the façade noise abatement, the approach proposed by EN ISO 12354-3 [29] was followed, by calculating the abatements from the façade insulation index normalized to the reverberation time $D_{2mnT,w}$[27] and the spectrum adaptation terms, and by comparing the results with data obtained in an experimental campaign carried out in two different buildings. An equalization of both the standard and the new spectra was necessary, in order to avoid the acoustic distortion due to the reproducing instruments. The standard one and the new spectra were then reproduced on the façade of a terraced house and a university classroom. The results obtained by using the spectrum adaptation terms C and C_{tr}, provided by the standard spectra N. 1 and N. 2, and the new terms C_j calculated from the proposed new mean spectra were finally compared [27,29].

2.1. Spectra measurements

Different noise spectra were considered, in order to evaluate their influence on the noise transmitted through the façade.

The noise spectra were registered in the field in two different measurement campaigns, in different traffic conditions, both for road and railway traffic. The measurement points were chosen in order to allow the best conditions for the noise acquisition and to avoid eventual disturbing sources next to the acquisition system. Measurements were carried out in significant periods of the day, when the traffic intensity was high, in working days, and with good weather conditions.

The road traffic spectra were recorded for 30 min, while the railway traffic spectra were recorded as the train passed; vehicles were counted by the measurement operators. Spectra were registered in 1/3 octave band by two different acquisition systems as dB-Steel SYMPHONIE and Sinus Soundbook, described in previous works [31–33].

They were chosen in order to be representative of the common characteristics of Italian roads and railways; in particular only conventional pavement surfaces were considered, excluding porous asphalts which are not very diffused, and normally used.

Different road categories were considered: highway, freeway, urban road, main road, generating very different noise spectra, depending on the road characteristics and on the vehicles rates, kind and speed. Furthermore the following road geometries were considered:

- Straight road (level and sloped roads).
- Roundabout.
- Traffic light crossing.

Also different railway traffic conditions were considered:

- Low speed trains (v < 140 km/h).
- Diesel trains (v < 120 km/h).
- High speed trains (v < 300 km/h).
- "Frecciarossa" trains (v > 300 km/h).

Twelve road traffic noise spectra were registered in the city of Perugia and its surroundings during the first campaign [32,33], while in the second one 15 spectra were obtained (signed with*):

- Highways (HW1*, HW2*).
- Freeways (FW1, FW2, FW3*, FW4*, FW5*, FW6*, FW7*, FW8*).
- Urban roads (UR1, UR2, UR3, UR4, UR5, UR6*, UR7*, UR8*).
- Main road (MR).
- Traffic lights (TL1, TL2, TL3*, TL4*).
- Roundabouts (RA1, RA2, RA3*, RA4*).

Twenty railway traffic noise spectra were furthermore registered during the two acquisition sessions:

- Low speed trains (LST, LST2*, LST3*).
- Diesel trains (D1*, D2*, D3*, D4*).
- High speed trains (HST, HST2*, HST3*, HST4*, HST5*, HST6*).
- "Frecciarossa" trains (FR1*, FR2*, FR3*, FR4*, FR5*, FR6*, FR7*).

In Tables 1 and 2 traffic noise sources and acquisition characteristics for the second campaign are showed, while for the first one the same features are described in a previous work [31].

In processing step, data were elaborated by means of the following softwares: dBFA, dBBATI32, dBTRAIT32 and dBTRIG by