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Incidence of the ventilation holes and the mechanical ventilation systems of façade on the noise insulation

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Abstract

This study will assess the influence on the acoustic insulation of façade of small elements such as ventilation holes or mechanical ventilation systems. These elements are present to ensure an appropriate air exchange, and they can be with or without heat recovery units. The noise insulation of façade, taking into account such ventilation holes, was evaluated starting from the calculations carried in accordance with the procedures laid down by the standard EN 12354 and performing measurements concerning specific case studies.

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Keywords: "acoustic insulation, measurements;"

1. Introduction

In a worldwide perspective the main part played by energy in the design of new buildings or in the refurbishment of existing buildings is standing out more and more. Speaking of which the notices of European Community COM/2011/112 “Roadmap for moving to a competitive low-carbon economy in 2050” of March 2011 and COM/2011/885 “Energy Roadmap 2050” of December 2011 have to be taken into account. As far as the standardization of procedures is concerned the EN 15251 norm [1] norm considers the assessment of the energy performance including further physical sets of problems such as the acoustic yields.

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The European standard EN 12354-3 describes a calculation method to estimate the reduction of outdoor sound by facades of buildings, its accuracy has been investigated in [1] in laboratory conditions obtaining satisfactory results. Airborne sound transmission between adjacent rooms can be predicted using the Standard EN 12354-1, corresponding to a first-order approximation of statistical energy analysis, it has been considered in [2] inferring the necessity of further validations. The façade abatements, predicted in compliance with EN ISO 12354-3, were analysed for mean spectra derived from in field measurements as urban roads etc in [3] rather than pink spectra giving a further contribution to the problem definition.

In the present work the predicted acoustic performance, obtained by applying the EN12354-3 norm, is compared with the performance, as measured in situ, of different types of facades, realized with the standard architectural systems of the Mediterranean area. More in detail the following types have been considered: buildings with architectural elements made of more layers of bricks and insulating sheets (type1), systems in load-bearing blocks made of bricks cladded with natural stone (type 2) and a multi layer system plus an insulation layer for the laboratory test wall (type 3).

Moreover the effect that small elements, like air vents, can have on the acoustic performance of the architectural element facade, have been evaluated. The goal of all this consists of highlighting with a "statistical weighting", the performance gaps encountered in buildings between the predicted results (obtained without confident data or with lacking data) and the in situ checks. Mechanical ventilation systems (MVS) are gaining more and more importance and prospects for development because of energy saving and climate control issues. They make use of the air intakes and deliveries to outdoor constituting a source of sound insulation weakening. In the present study measurements a calculations apply essentially to simple ventilation holes but they may also be extended to MVS. That is especially in the case of punctual MVS, equipped with piping with a single outer hole that operates by an alternating flow. Punctual MVS therefore do not differ from ventilation holes and the insulation provided by them becomes the essential element.

Nomenclature

A_0	Reference area[m^2]
D	Sound reduction[dB]
R	Sound insulation[dB]
R_w	Sound insulation index [dB]
R'	Apparent sound insulation [dB]
R'_w	Apparent sound insulation index [dB]
S	Area of a façade element [m^2]
$D_{2m,nT}$	Acoustic insulation of façade [dB]
$D_{2m,nT,w}$	Acoustic insulation of façade index [dB]
T_0	Reference reverberation time[s]
V	Volume of the receiving space [m^3]
ΔL_{fs}	Correction for the façade shape[dB]
τ	Acoustic transmission coefficient

2. Prediction of performance by calculations

The prediction of the acoustic insulation provided by the various analyzed elements of the facade has been calculated by following the procedures included in EN 12354-3 norm [4]. The input data to the calculation model have been drawn from different sources: statements of the manufacturers of architectural systems, data bases annexed to different norms, estimations via prediction formulas. In prediction calculations all the façade elements have been assumed, for each category, to present the same architectural features (standard facade) The calculation has been carried out by using the formulas available in [4], used in their simplified form and acquiring the performance indices on the basis of standardized procedures [6]. The prediction equations are recalled hereinafter:

$$D_{2m,nT} = R' + \Delta L_{fs} + 10\log\frac{V}{6T_0 S}. \quad (1)$$

$$R' = -10\log\left[\sum_{i=1}^{n}\tau_{e,i} + \sum_{f=1}^{m}\tau_f\right] \quad (2)$$

In the employed equations the components of indirect transmission τ_F (paragraph 4.1 in [4]) have been neglected, applying an overall corrective coefficient K_e ,equal to 2 dB, for stiff elements; moreover the acoustic insulation given by the small elements included in the façade is considered, as the box of rolling shutter ($D_{n,e,b}$) and the air vent ($D_{n,e,h}$), as shown in the following formula:

$$R'_w = -10\log\left[\frac{S_{wall}}{S_{tot}}10^{\frac{-R_{wall}}{10}} + \frac{S_{win}}{S_{tot}}10^{\frac{-R_{win}}{10}} + \frac{A_o}{S_{tot}}\left(10^{\frac{-D_{n,e,b}}{10}} + 10^{\frac{-D_{n,e,h}}{10}}\right)\right] - K_e \quad (3)$$

The sound insulation R_w does not take into account indirect transmission, just direct transmission. It is applied to the single elements of the façade.

3. Prediction of façade sound insulation

The prediction has been calculated in a simplified way, evaluating the performance indices and considering their change as the acoustic insulation of the air vent varies. The results of these calculation are shown in the following diagrams in which is pointed out how the improvement of the performances of the installed window become non influential as the insulation given by the air vent and by the box for rolling shutter decreases.

In detail in order to comply with the limit of 40 dB for the insulation of façade D2m,nT,w, as the insulation of the wall is defined, three curves can be drawn by the values of D_{neh} (just the air vent reduction) needed after three values for D_{neb} have been set, namely 45,44 and 43 dB. The above limit affects the acoustic project of a façade and all its various elements play a role.

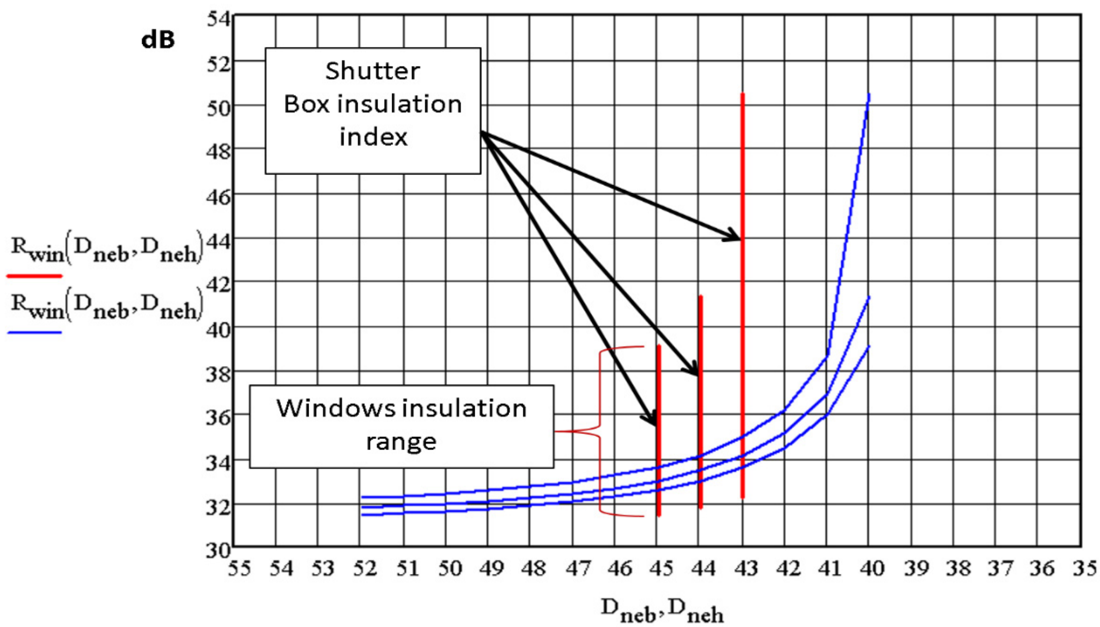

Figure 1: Variation of the required performance for windows.

The diagram shown in figure 1 has been obtained by making use of the starting equations (1) and (2), which are included in the calculation standards [2,9]. After deducting from the previous formulas the sound insulation index for the window as a function of the small elements included in the façade, the equation (4) has been obtained and used to plot the diagram in figure 1.

$$R_{win}\left(D_{n,e,b}, D_{n,e,h}\right) = -10\log\left\{\frac{S_{tot}}{S_{win}}\left[10^{\omega} - \frac{S_{wall}}{S_{tot}}10^{\frac{-R_{wall}}{10}} - \frac{A_o}{S_{tot}}\left(10^{\frac{-D_{n,e,b}}{10}} + 10^{\frac{-D_{n,e,h}}{10}}\right)\right]\right\} \qquad (4)$$

where the letter ω denotes the term:

$$\omega = \frac{-D_{2m,nT,w} + \Delta L_{fs} + 10\log\left(\frac{V}{6T_oS}\right) - K_e}{10} \qquad (5)$$

Following the same procedure it is possible to get the soundproofing performance needed by the air vent, as a function of the sound insulation index of the wall and of the window.

$$D_{n,e,h}(R_{win}, R_{wall}) = -10\log\left\{\frac{S_{tot}}{A_o}\left[10^{\omega} - \frac{S_{wall}}{S_{tot}}10^{\frac{-R_{wall}}{10}} - \frac{S_{win}}{S_{tot}}10^{\frac{-R_{win}}{10}} - \frac{A_o}{S_{tot}}\left(10^{\frac{-D_{n,e,b}}{10}}\right)\right]\right\} \qquad (6)$$

From the previous equation, the diagram in figure 2 is plotted and shows that the insulation performance of the air vent has to be higher or equal to 39 dB in order to guarantee an insulation performance of the façade D2m,nT,w not less than 40 dB, even if both the opaque wall and window provide an high performance.

In fig. 2 at left 5 curves are drawn for 5 values of the window insulation R_{win} in the range 32-40 dB. They show the threshold that the sound reduction of the air vent D_{neh} has to reach in order to guarantee the required insulation of façade versus the wall insulation R_{wall}, ranging from 30 to 60 dB. In figure 2 at right such curves of D_{neh} are pointed out , showing an asymptotic trend for high wall insulations R_{wall} to values that depends on window insulations R_{win}.

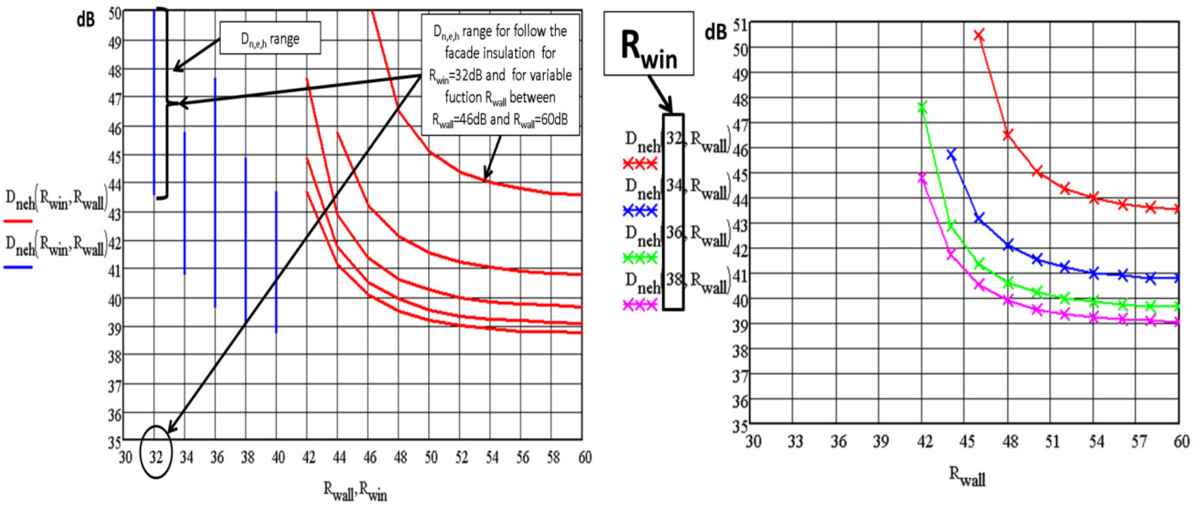

Figure 2: Acoustic insulation required for the air grills or punctual MVS systems versus the acoustic performance of the wall and of the windows.

4. In situ measurements and test laboratory measurements to assess the influence on insulation due to ventilation holes or punctual MVS systems

The in situ measurements concerning the airborne acoustic insulation of façade elements have been carried out between years 2013 to 2015, in accordance with ISO 140-4 standard [9] and, subsequently, the new ISO 16283 standard series [11,12], using as a sound source an artificial source consisting of a directive loudspeaker.

4.1. Measurements of façade sound insulation made on two types of building components

The measurements here shown have been carried out on several new buildings which have been realized by different manufacturers with the same architectural typology: this allowed to take into account the different workers' job, as it can affect to a significant extent the performance results in situ. Here you find the diagram where the in situ measurements are drawn as a function of frequency for the different façade types considered (Figure 3 and Figure 4).

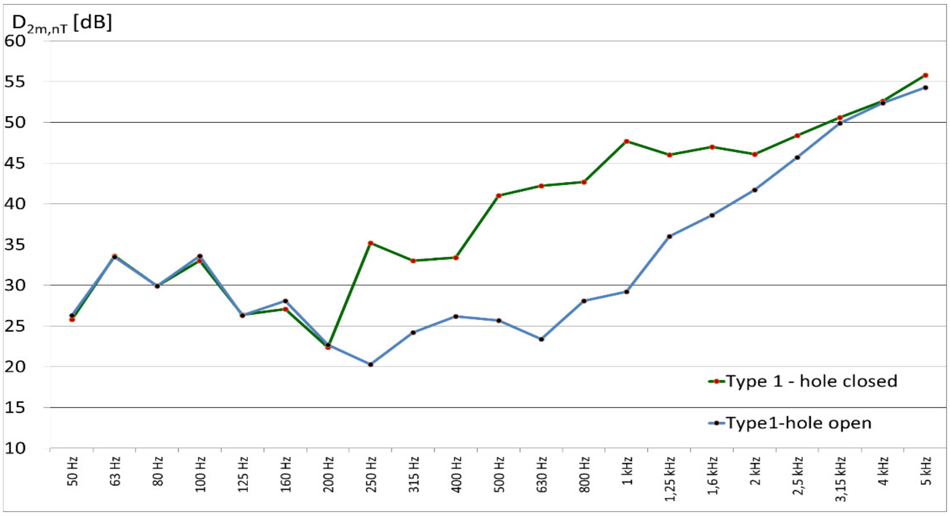

Figure 3: Acoustic insulation of façade (type wall 1), as measured in situ, for different configurations of air vents.

The influence of the air vent is apparent, especially as the central frequency range is concerned. Without such an element the acoustic insulation of façade gets a gain up to 15 dB (Fig. 3). The trend is different for the type 2, where the air vent presence counts mainly in the medium and high frequency range.

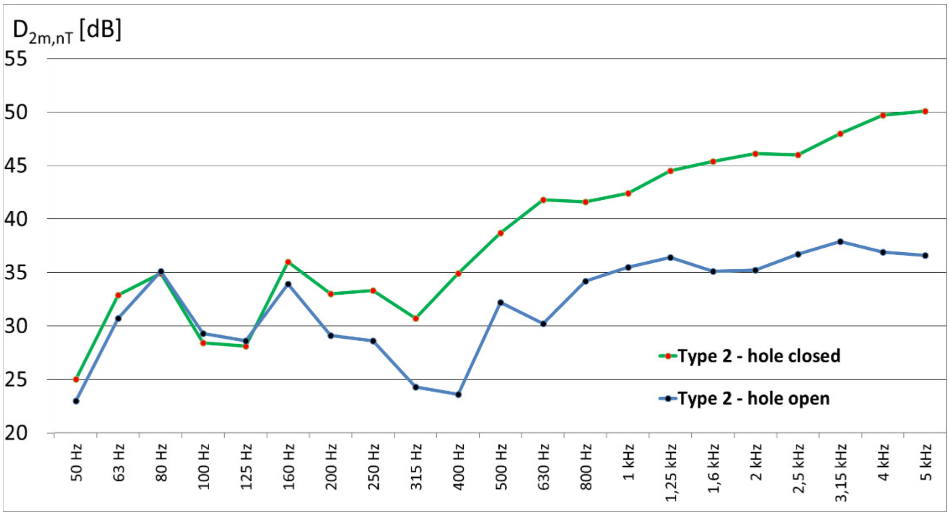

Figure 4: Acoustic insulation of façade (type wall 2), as measured in situ, for different configurations of air vents.

4.2. Test laboratory to assess the influence due to the ventilation hole or MVS systems

The test laboratory consists of two rooms connected through an opening (gap) 12 m² wide inside a reinforced concrete frame. The two rooms with the same height (3.40 m) are characterized by a slightly different (areas 24.57 m² e 23.77 m² respectively). In order to ensure a proper sound diffusion in the low frequency range too, the vertical walls are atilt, while floor and ceiling are parallel. All the internal surfaced are strictly smooth in order to allow the sound is highly reflected. Both the rooms have a single entry with double door.
The layout of the test laboratory in accordance with ISO standard [13,14] is shown in the figure 5.

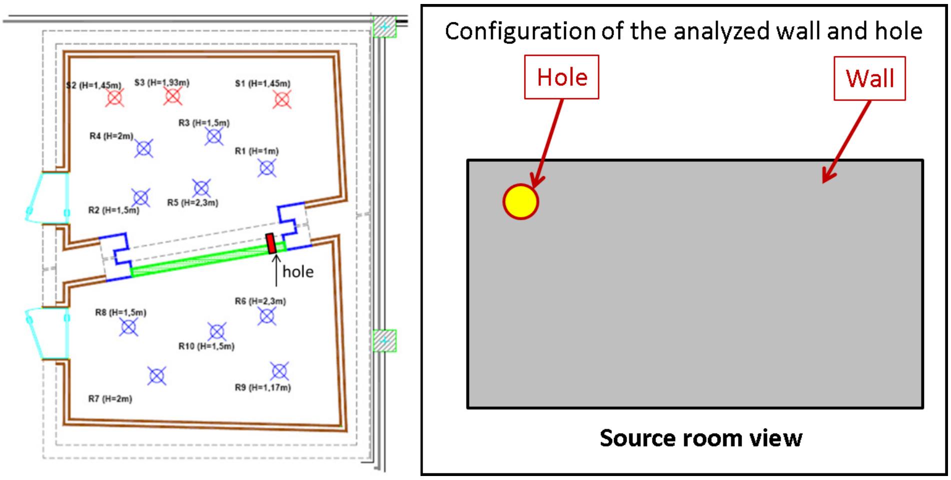

Figure 5: Layout of the test laboratory.

4.3. Results from measurements in test laboratory

The wall analyzed in the laboratory tests [13,14], is denoted as “Type 3”. The measurement of the sound insulation index has been carried out on such a wall at first without the air hole (bricked up) and then with it. The obtained results are shown in figure 6, where the results of two measurement campaigns (m1 and m2) are shown.

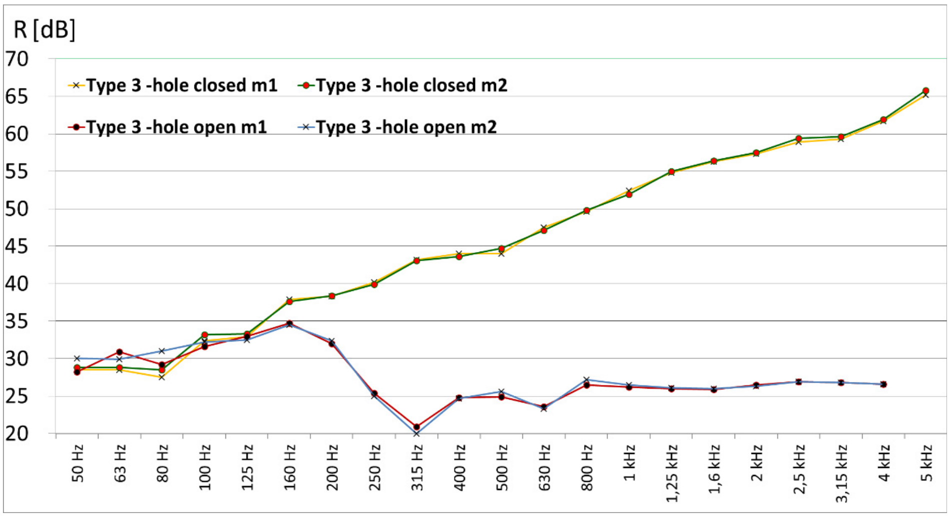

Figure 6: Laboratory measurements of influence of the sound insulation element.

5. Comparison and conclusions

From the analysis of the prediction models and the evaluation of experimental data measured in situ and in laboratory the essential role that the small elements included (air vents and other) play in façade sound insulation appears clearly.
In table 1 the performance indices are reported after the detailed levels for each frequency, have been shown and discussed, placing alongside the performance with and without holes for each type. For each typology, the spectral performance with and without the air hole have been compared highlighting a strong difference for specific frequencies. The indices are deduced from the spectra within the 100-3150 Hz frequency range and summarize the performance of the walls with and without hole opening.

Table 1: Performance indices calculated after measurements, § 4.1 and 4.3.

Index	Type 1 (hole closed)	Type 1 (hole open)	Type 2 (hole closed	Type 2 (hole open)	Type 3 (hole closed	Type 3 (hole open)
D_{nT} and R Index	$D_{nT,2m,w}=42$	$D_{nT,2m,w}=30$	$D_{nT,2m,w}=42$	$D_{nT,2m,w}=33$	$R_w=52$	$R_w=26$

The present study showed that it is essential, at the design stage and constructor, to use certified insulation systems for ventilation able to provide an high acoustic insulation whenever aeration holes and VMC systems are present. The minimum values of acoustic insulation required for the ventilation system, at the design stage, in order to achieve in work of acoustic performance of the façade, can be obtained with the method accounted for in the present work.

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