Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 78 (2015) 1653 – 1658

Energy Procedia

6th International Building Physics Conference, IBPC 2015

Noise reduction interventions in the urban environment as a form of control of indoor noise levels

Magrini A.[a*], Lisot A.[b]

[a]*Department of Civil Engineering and Architecture - University of Pavia, Italy*
[b] *Department of Civil Engineering - State University of Maringà, Paranà, Brasil*

Abstract

Traffic noise is a major problem in all large cities and the sound propagation in the urban context is reinforced by the multiple reflections on the building façades. The surface acoustical characteristics (e.g. referred to roads, pedestrian traffic areas, building facades, building surfaces in general) affect the noise propagation in the urban environment. Through a better outdoor design and management (e.g. by means of green areas, porous asphalt, speed control), or building refurbishment actions (acoustic plaster, absorbing shading devices), the increasing of surface absorption could be useful to mitigate noise environmental pollution and therefore to reduce the sound levels in the proximity of the building façades for their entire height.

The reduction of the noise levels outside the buildings would determine lower indoor noise levels and therefore a better situation, without direct actions on the building walls. Through a series of noise propagation calculations in urban environments, by means of a three-dimensional simulation model, the influence of some configurations, and the potential impact of some intervention solutions, will be quantified. In the first stage of the research, the analysis of a simplified model is conducted, to evaluate the influence of noise on the buildings facades, based on a simplified geometry of the urban environment and of the surface acoustic features. The same analysis is validated by means of a more detailed model, corresponding to the configuration of an existing built area, to verify if the analyses performed by means of the simplified model can be extended to more complex layouts.

Successively, calculations are developed to quantify the noise levels that occur with different acoustic (absorption of facades, soil, asphalt, or green elements) and geometric (road width, buildings height, presence of balconies, etc.) characteristics, to show the potential reduction given by some interventions. Solutions that can lead to a more significant reduction of the noise in correspondence of the facades are then discussed.

Peer-review under responsibility of the CENTRO CONGRESSI INTERNAZIONALE SRL

---

* Corresponding author. . Tel.: +39-0382-985724; fax: +39-0382-985589.
E-mail address: magrini@unipv.it

Peer-review under responsibility of the CENTRO CONGRESSI INTERNAZIONALE SRL
doi:10.1016/j.egypro.2015.11.246

Keywords: Building façades; urban canyon; noise pollution.

Nomenclature

d	horizontal distance [m]
h	building height [m]
h_r	receiver height [m]
L	Sound pressure level [dB(A)]
w	road width [m]

1. Introduction

The urban noise is a problem to face quite in all the cities, due to traffic, industries, and various activities. The attention to the noise pollution problem has grown in the last years. Measures to control and reduce the outdoor and indoor noise levels have been indicated. References for the assessment and management of environmental noise in Europe are indicated in the Directive 2002/49/EC [1]. Regulations to limit the noise inside buildings have been generally prescribed at national level, with indications on the requirements of the building façades, to guarantee suitable protection from outdoor emissions.

Although the more recent buildings must comply with these requirements, the older ones were often designed with poor attention to the sound insulation. In some cases is not possible to consider the acoustic improvement of each building, if not associated to other actions (i.e. thermal insulation for energy refurbishment, façade restoration), mainly for economic reasons.

However, the reduction of the road noise levels, planned to increase the outdoor acoustic quality, can influence positively the noise levels in the proximity of the facades, for their entire height, without modifying the sound façade insulation. It would determine lower indoor noise levels and therefore a better situation, without direct actions on the building walls.

The influence of building shape and façades on the noise levels can be considered in the urban planning jointly with other elements that may contribute to obtain reduced levels of noise pollution [2]. For example, balconies can influence the noise field and their appropriate design could contribute to the noise control effectively. An analysis of the insertion loss due to rectangular balconies on a building façade, jointly with the sound reflection and scattering effects from adjacent balconies, show that the front panel of the balcony determines the screening performance, while the sidewalls of the balcony are insignificant. Moreover, in the absence of a front panel, no acoustic protection can be highlighted, due to the upper balcony reflection, especially for a distant noise source [3]. An interesting solution to reduce the impact of traffic noise on the building façades has been realised by means of ceiling-mounted reflectors, showing a reduction of road traffic noise up to 7–10 dB(A), compared to an ordinary balcony and indicating a corresponding effect as absorbent ceiling [4]. Correct choices or modifications in the design or restoration processes can reduce noise annoyance and sleep disturbance indoor [5]. The use of simulation by means of a simplified geometric model may allow to limit costs, even if the results can be affected by low accuracy. After all, more detailed models are influenced by a certain approximation level, due to the computational scheme. From studies on the influence of diffusely reflecting façades in wide city street canyons, the geometrical reflections were shown to underestimate the total sound pressure level for large source/receiver distance, due to neglecting the diffuse-scattering phenomenon [6]. In the following, some calculations are performed to show the impact of simple actions on the outdoor noise, on the building façades, taking into account of different urban layouts. The aim was to evaluate the influence of noise on the buildings facades, on the basis of the geometry of the urban environment (road width, buildings height, presence of balconies, etc.) and of the surface acoustic features (absorption of facades, ground, asphalt, green elements), by means of simplified geometrical models. A first step of the research has been dedicated to validate the simplified geometrical model, and then some variations of the significant parameters have been considered, by means of the simplified configuration, to show that it can be used to obtain quantitative information on the suitable actions.

2. The simulation method and procedure

The calculation method is based on a three-dimensional simulation model of noise propagation in urban environments (SoundPlan) that allows to quantify the influence of some architectural configurations and the potential impact of possible intervention solutions.

2.1 Simplified geometrical model

The first calculations were conducted on a simplified geometrical model of a straight road (100 m length, four width cases, w = 12-16-20-24 m, each including two sidewalks, 3 m width), between two continuous rows of buildings of the same height. (Fig.1). The sources have been positioned on the middle of the road (h_r = 0.6), the receivers are located on the sidewalks, d = 0.5 m from the building façade (h = 1.5 m, 4.5, 7.5, …step 3m, up to 30m, to consider a receiver for each floor).

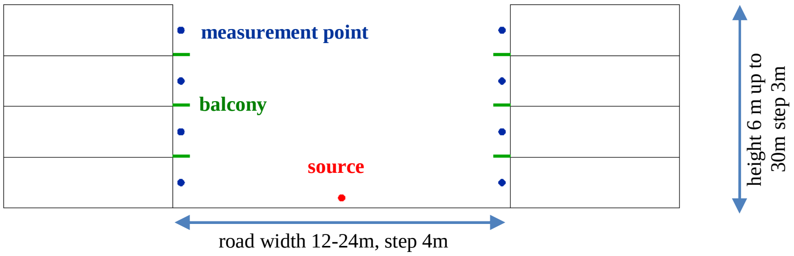

Fig. 1. Building layout for the simplified geometrical model

2.2 Existing layout model

To quantify the approximation level of the results that can be obtained by using the simplified geometry model, a real urban layout has been considered, with the aim to verify how affordable can be the results, although with reduced calculation times. From the analysis of the buildings layout of an existing town (Maringá, Paraná, Brazil), the urban plan has been considered, taking into account of the distribution, the occupation of the areas, and the width of the roads corresponding to the real case (Fig.2). The same measurement points of the simplified model have been considered in the cross-section of the road.

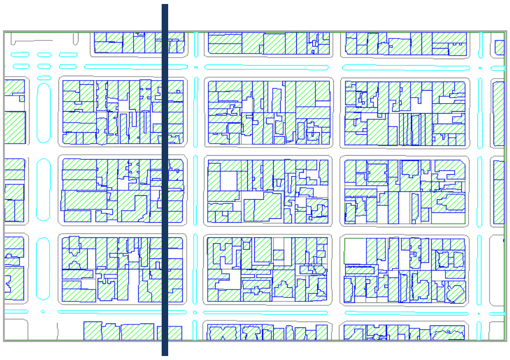

Fig. 2. Building layout for the existing town – The line indicates the analyzed cross section

Fig. 3 shows the cross-section, of the real situation: the "Avenida Brasil" (w = 35 m), the "Avenida XV de Novembro" (w = 30 m), and the "Rua Santos Dumont" and the "Rua Neo Alves Martins" (both w = 20 m).

Considering the analyzed section, "Rua Santos Dumont" have buildings with h = 13.5 m only on one side of the road. The same happens in "Avenida XV de Novembro" where buildings have h = 7.5 m. In "Rua Neo Alves Martins" there are high buildings on both sides of the road, but not in the analysed cross section. So, in this road, only receivers up to h = 4.5 m have been analyzed.

The comparison has been performed considering the same acoustic absorption of surfaces in the two configurations. In the existing layout, the measured sound pressure level in each road was considered (L = 80-86 dB(A)), while in the simplified model the same mean value is assumed (L=85dB(A)). The results of the two different approaches were compared in terms of attenuation (difference between source and façade sound level), to quantify the deviation (see next clause 3).

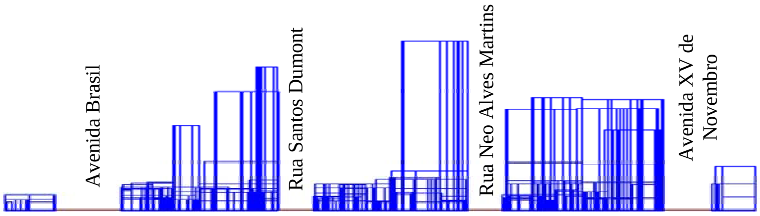

Fig. 3. Cross section – urban layout

In a second phase of the analysis, by means of the simplified configuration, some variations of the significant parameters have been considered:

- the height of buildings (from h = 6 m up to 30 m, step 3 m);
- the presence of glass surface, acoustic plaster, and their percentage on the façade (by means of a mean absorption coefficient a = 0.02 - 0.6);
- the presence of balconies on multiple levels (second, third, fourth floor, ... up to the tenth floor), by adding a horizontal screen of 1 m width for the whole extension of the buildings along the road, at h = 3 m, 6 m, up to 27 m (step 3 m), to simulate up to 9 levels balconies (in Fig.1 in green) ;
- the presence of green areas / gardens / urban parks (trees / soft green ground) and acoustic asphalt for the road and sidewalks, through the absorption coefficient values a = 0.1 , 0.4 , 0.9;
- the control of the vehicles average speed, taken into account with different Sound Pressure Levels of the sources.

3. Analysis of the results – validation of the simplified model

The comparison of the results of the simplified geometrical model and the existing urban layout were represented to show the sound attenuation at a distance 0.5 m from the facade of the buildings in the analyzed section (Fig.4).

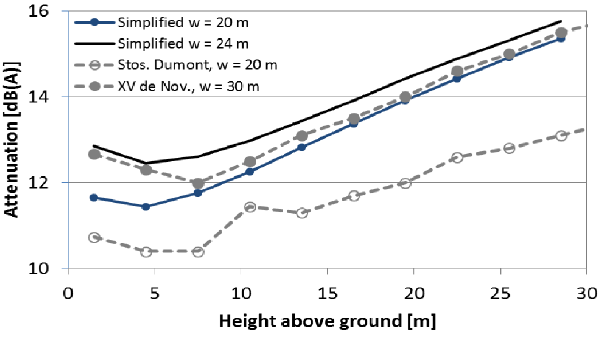

Fig.4. Comparison between simplified geometrical model and real case

The most representative situations (Avenida XV de Novembro and Rua Santos Dumont), characterized by higher buildings, are represented in comparison with the simplified geometrical model, referring to four road width w = 20, 24 m (Fig.4). Comparing the results of the "Avenida XV de Novembro" (w = 30) and "Rua Santos Dumont" (w = 20), the reduction of the noise level with the height is more pronounced for the first one. This is explained by the fact that wider roads allow greater noise reduction, as the distances are higher, as it can be observed in the simplified tests;

moreover, even if the "Rua Santos" analysed section presents high buildings, the building height is more irregular in the surroundings. The maximum difference that can be observed between the two models reaches 2.3 dB(A), corresponding to 17% of overestimation compared to the actual value, for w = 20 m.

4. Analysis of the urban refurbishment actions by means of the simplified geometrical model

As said before, at the end of the first stage, the simplified model shows to be affected by a maximum error of 17% on the results, valid for the most irregular road layout. In the second part of the analysis, different combinations of input parameters have been considered, by using the simplified model, to show the potential noise level reduction related to geometrical features and surface characteristics. The following considerations can be highlighted.

A) Varying the **mean buildings height** allows to take into account different building layout and the more or less pronounced effect of "urban canyon". However, it does not affect significantly the sound field for buildings height up to 30 m, either at the road level, or on the façade (Tab.1). The simulations have been performed with two rows of building of the same height facing a road. Two series of simulations were performed with mean high and low **absorption coefficient** (to take into account the presence of transparent and opaque surfaces in a different percentage). The reflections between the facing surfaces of buildings seem to be not relevant. Varying the **width of the road**, the same behaviour is observed (no influence of the height of the buildings), even if lower sound levels in façade are obviously obtained.

Table 1 - Effects of the building height and of the road width

Mean building height	h = 6, 9, 12, 15, 18, 21, 24, 27,30 m		no relevant influence
Absorption coefficient	a = 0.02 and 0.6		no relevant influence
Noise Level Difference referring to 12 m road width, h = 30 m	16 m width	20 m width	24 m width
Receiver close to the façade, h = 1.5 m	- 1.6 dB(A)	- 2.9 dB(A)	- 4.1 dB(A)
Receiver close to the façade, h = 28.5 m	- 0.4 dB(A)	- 0.8 dB(A)	- 1.2 dB(A)

B) The influence of the absorption properties of the buildings surfaces on the sound field was analysed along the façade: high absorption coefficient (a=0.6) of the building walls allows lower sound levels close to them (Fig.5). The use of **absorbent plaster on the façade** of w =12 m road provides a reduction of 1.5 dB(A) (average level) in the receiver at h = 1.5 m and up to 3.3 dB(A) in the receiver positioned at h = 28.5 m. These values become respectively 1.6 dB(A) and 3.1 dB(A) for w = 16 m road; 1.6 dB(A) and 2.9 dB(A) for w = 20 m road; 1.5 dB(A) and 2.8 dB(A) for w = 24 m road.

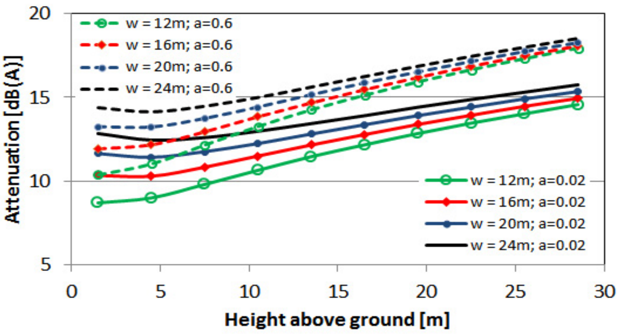

Fig. 5 Attenuation effects for different road width and sound absorption

With the same road width, the absorption effect is more marked at the highest positions on the facade: the difference between the sound level with a = 0.02 and 0.6 is greater (in Fig.5 the two groups of lines diverge). The effect is more evident for narrow streets (higher line of each group) where the difference is 3.3 dB(A) while it is 2.9 dB(A) for wider roads (w = 24 m), on the top of the 30 m high building (h = 28.5 m).

C) In some urban configurations, **balconies** are almost absent (curtain walls) while in other cases they may represent an important part of the external surfaces. The balconies have been considered as fully reflective screens, since the simulation of their absorption features is not possible with the adopted software. The façade with balconies change the sound field near the surface of the building for all the widths of the road even if the effect is less significant for the widest road.

Table 2 - Effect of the presence of balconies

Noise level reduction referring to the absence of balconies	w = 12 m	w = 16 m	w = 20 m	w = 24 m
a=0.02, h_r = 1.5 m	≅ 0	≅ 0	≅ 0	≅ 0
a=0.02, h_r = 28.5 m	- 7.9 dB(A)	-6.2 dB(A)	-5.6 dB(A)	-5.3 dB(A)

With low absorption coefficient, the presence of the balconies does not change the average sound level at h_r = 1.5 m, while it produces good reduction for the receiver at h = 28.5 m, compared to the corresponding case without balconies (Tab.2). Higher facade absorption doesn't produces significant higher reduction of the sound level.

D) The receiver position, h_r = 1.5 m, is influenced by the **ground absorption effects** more than the other positions, and the corresponding sound pressure level is slightly lower than the position above. The presence of **green areas and absorbent paving**, represented by an absorption value of a = 0.9, doest'n seem to affect significantly the sound levels close to the façade, at least in relation to the considered extension of the road (w=12 to 24 m) and the traffic noise levels (L = 75 and 85 dB(A)). This is probably due to the small ground surface, in comparison with the extension of other considered surfaces.

E) Besides all, the control of the **average speed of the vehicles**, as a function of traffic flow, produces good results on the façade: the absolute reduction of the average noise level of 10 dB(A) (from 85 to 75 dB(A)) shows the same attenuation as before, also for the highest floors.

Conclusions

The possibility to use a simplified geometrical model to obtain affordable information on the noise reduction in the urban environment was analysed. For this purpose, the results obtained by means of a simplified geometrical model and through the modelling of an area of a medium-sized city, characterized by modern buildings (Maringà, built since the 60s) have been analysed. The results obtained by the simplified geometrical model can be considered acceptable for a first level investigation, as they appear to be affected by a maximum error of 17%, compared with the model of the effective urban layout. The simplified model has been therefore used to analyse the influence of green areas and absorbent paving, of the absorption properties of the buildings surfaces and the presence of balconies, of some geometrical features (buildings height, road width), and of the control of the average speed of cars, to evaluate the possibility to reduce the computation times.

The sound attenuation close to the façades can be effectively evaluated also in the simplified geometrical model, if the buildings surfaces facing the roads are evenly distributed. The true layout must be considered when the surfaces are not regular and their distribution is more complex.

References

[1] Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise, Declaration by the Commission in the Conciliation Committee on the Directive relating to the assessment and management of environmental noise (2002).

[2] M. F. Oliveira, L. T. Silva, The influence of urban form on facades noise levels, WSEAS Transactions on Environment and Development, Issue 5, Volume 7, May 2011.

[3] K. Attenborough, K. Ming Li, K. Horoshenkov, Predicting Outdoor Sound, CRC Press, 2006, ISBN 0203088735, 9780203088739

[4] SK. Tang, Noise screening effects of balconies on a building facade. J Acoust. Soc Am. 2005 Jul;118(1):213-21.

[5] European project QSIDE - The positive effects of quiet facades and quiet urban areas on traffic noise annoyance and sleep disturbance, LIFE09ENV/NL/000423

[6] T. Ishizuka, K. Fujiwara, Traffic noise reduction at balconies on a high-rise building façade, J. Acoust. Soc. Am. 131, 2110 (2012); http://dx.doi.org/10.1121/1.368205