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Acoustic screening effect on building façades due to parking lines in urban environments. Effects in noise mapping

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ABSTRACT

European Directive 2002/49/EC indicates that strategic noise maps are the main tool for assessing the exposure of the population to environmental noise. When these are made through computational methods, the presence of lines of parked vehicles on the sides of urban streets is not usually considered, but recent studies suggest the possibility that its effect on real exposure to noise on buildings façades is not negligible. In this study, the effect of parking lines in urban street design on sound level distribution is numerically studied with the Boundary Element Method (BEM). A screening effect associated with the presence of parking lines is observed. This effect varies depending on the height for measurement and the distances between the sound source, the parked vehicles and the facade of buildings. The results show that the effect can be significant in many urban street configurations in order to determine the exposure to traffic noise of dwellings. As a consequence, by not considering it in noise mapping, the accuracy of the outcomes of noise maps conducted according to European Directive can be influenced.

1. Introduction

Noise pollution is considered today as one of the main environmental problems in cities, cited by the World Health Organization [1] as the second among a series of environmental stressors for their public health impact in a selection of European Countries. In this regard, as outlined in the European Directive 2002/49/EC [2], strategic noise maps are the main tool for assessing the exposure of the population to environmental noise.

Different strategies can be considered for noise mapping. One is the elaboration of noise maps through computerized methods, usually performed by different commercial software, whereas a second option is "in situ" measurements [3–6].

One of the references for the evaluation of noise pollution outdoors are the international standards ISO 1996-1: 2003 and ISO 1996-2: 2007 [7,8], which have helped as a basis for the development of both national and international legislation, because, among other things, they describe aspects of the calculation and measurement procedure of sound pressure level outdoors. Other references in this regard are the standards ANSI S12.9-1, ANSI S12.9-2, ANSI S12.9-3 and ANSI 12.18 [9–12], which describe the procedures for the description and measurement of environmental sound and, in the latter case, for the outdoor measurement of sound pressure level.

If it is intended to determine the noise level incident on the façades of buildings in a particular urban environment, it is known that this parameter depends on multiple factors, both temporal [13–18] and spatial [19–23]. Thus, for an adequate evaluation, it will be necessary to consider not only the characteristics of the source, but also the situation of the measuring point relative to the source and the specific urban environment of each street or façade assessed; and therefore, the effect on the measurement result that the different elements or configurations of urban environment will have [24].

In connection with this topic, many workers consider the urban design of streets as an important factor to reduce the exposure of the population to traffic noise. Echevarria et al. [25] study the impact of building shape and street geometry on people's noise exposure. Variations of up to 7.0 dB(A) occur for pedestrians depending on the building shape; substantial reductions of noise exposure at windows are obtained related to building-façade design. Jang et al. [26] use a scale-model method for measuring noise reduction in residential buildings due to vegetation in façades. The results show that the noise reduction due to the vegetated façades was less than 2 dB at pedestrian level in a two-lane street canyon. Sakamoto et al. [27] perform a numerical and experimental study on the noise shielding effect of eaves/louvers attached on building façades, concluding that the inclined type

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eaves are effective as a noise reduction measure. Castiñeira-Ibañez et al. [28] conduct a study about how building façades can be protected from transport noise using acoustic barriers based on arrays of isolated scatterers.

In this regard, some researchers consider that the results of noise mapping are very important in the design of buildings in urban streets. On the one hand, Kurra et al. [29] describe a model to determine the required insulation performances for buildings' external elements using strategic noise maps. An insulation map is proposed as a visual tool that could facilitate building noise control and could be utilized in preparation for building specifications before the construction phase and in developing the insulation codes by local administrations. On the other hand, Barclay et al. [30] present a method to quantify the interaction of building noise exposure with natural ventilation potential. Their results show that the introduction of noise reduction equal to 10 dBA resulted in reductions in cooling energy consumption that varied from 28 to 45% of the original cooling energy consumption.

In the same manner, others works study the influence of common elements in sound field propagation in urban environments. Van Renterghem [31] tries to evaluate the screening effect produced by the presence of hedges in urban streets of different cities in Europe. As a sound source, both light vehicle traffic and white noise emitted by an omnidirectional speaker were used. Hedges of different dimensions are analysed by the "in situ" and computerized methods. The conclusions obtained indicate that the analysed hedges provide a small reduction in the noise level for light vehicles at low speeds. The medians of experimental values obtained for the noise reduction in each case range between 1.1 and 2.8 dBA, depending on the characteristics of the hedge and other parameters such as vehicle speed and the height of the microphone.

Montes González et al. [20] study the effect of the variation of microphone position in height and distance to the building façade. To do this, simultaneous measurements are made using two sound level meters at several points in the city with different urban geometries. Based on the analysis of the differences of the sound level in octave bands, the results show the existence of a possible shielding phenomenon associated with the presence of lines of parked vehicles on the sides of urban streets, whose effects are important above 250 Hz, so that sound level meters placed higher record greater values of sound level. This fact is observed even for the comparison between the measurement positions at 4.0 and 6.0 m height.

Another issues of considerable relevance in noise mapping, to evaluate the results obtained by both simulations and "in situ" measurements, are the sound source characteristics. In this way, the ISO 1996-2 standard establishes some generalities to be considered for all types of sound sources, adding some considerations for certain particular types of sources, such as road, rail and air traffic, etc. However, they are related to the representativeness of the measurement with respect to the average conditions of the source in the environment under evaluation, so this standard does not assess the effect that each of the source parameters may have on the results of the measurements.

Since in this case road traffic is considered as the sound source, a parameter such as the height associated with the sound source could be of interest. In this sense, Jonasson's study [32] of the propagation model Nord 2000 for road traffic proposes that each vehicle be represented by six point sources; three situated at heights of 0.01, 0.15 and 0.30 m for modelling the rolling, engine, exhaust and aerodynamic noise. For the remaining three sources, varying heights are proposed depending on the type of vehicle. Later, a new report was published for modelling sound sources [33], related to the Harmonoise method [34]. [33] proposes that each vehicle be represented by two point sources, one simulating the contribution of road noise (0.01 m), and the other the propulsion noise (0.30 m for light vehicles and 0.75 m for heavy vehicles). The French standard NF S 31-133 [35], recommended by the European Commission for traffic noise in Directive 2002/49/EC [2], suggests that elementary point sources with a height of 0.5 m should be used for road traffic. Subsequently, Directive 2015/996 [36] proposes common methods for noise assessment that replace those indicated in Directive 2002/49/EC, where the use of an equivalent point source at a height of 0.05 m above the ground is indicated for light, heavy and two-wheel vehicles.

Another aspect of interest concerning the sound source in computational methods for the case of road traffic is the location of the equivalent source with respect to the longitudinal axis of vehicles, when they circulate in a lane. In this sense, [33] concerned acoustic modelling of sources for road traffic, using the longitudinal axis of the vehicle located in the nearest wheel as a reference point for modelling. On the other hand, Directive 2015/996 [36] indicates that the ideal case is to represent each lane with a line of sources located in the centre of each lane, which therefore correspond to the centre of the vehicle in the longitudinal direction.

Research on sound field propagation, mainly related to aspects like traffic noise and the urban environment, is extensive [25,37]. A wide variety of methods has been used to study the sound field behaviour in different types of environments: the boundary element method (BEM) [38–41], the finite element method (FEM) [42–44], the method of finite difference time domain (FDTD) [45–47], and the method of fundamental solutions (MFS) [48,49] are examples of the most common numerical methods used in this area of research.

Here, we present a study of the shielding phenomenon associated with the presence of lines of parked vehicles on the sides of urban streets [20] and its possible influence on the accuracy of the results obtained for the incident sound level on the façades of buildings when strategic noise maps are made through computational methods. Section 2 describes the numerical model used to this end by the boundary element method (BEM) in two dimensions. In Section 3, some parameters mainly related to the geometry of the street have been modified to analyse whether they are relevant in the propagation of sound outdoors.

2. Methods

Following the description of the problem and of the state-of-the-art in the introduction, let us now define the methods and parameters used for the analysis. The numerical method (BEM) will be briefly described, and an overview of the analysis performed is given.

2.1. Formulation of the BEM

As noted above, we study the phenomenon of shielding associated with the presence of lines of parked vehicles on the sides of urban roads. For this purpose, a numerical model using the boundary element method (BEM) in two dimensions has been elaborated as a first approach to the problem.

The BEM model used here is formulated in the frequency domain, solving the conventional Helmholtz equation normally used in acoustic analysis, of the form

$$\nabla^2 p(\mathrm{x},\omega) + \left(\frac{\omega}{c}\right)^2 p(\mathrm{x},\omega) = 0 \qquad (1)$$

where $p(\mathrm{x},\omega)$ is the acoustic pressure at point x for an excitation frequency ω, and $\nabla^2 = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}$ for 3D problems, and $\nabla^2 = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}$ for 2D problems. When 2D problems are considered, the effect of a harmonic source located at position x_s can be written as