Building and Environment 49 (2012) 291–303

Contents lists available at ScienceDirect

Building and Environment

journal homepage: www.elsevier.com/locate/buildenv

Sound insulation design by using noise maps

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A R T I C L E I N F O

Article history:
Received 26 April 2011
Received in revised form
23 June 2011
Accepted 11 July 2011

Keywords:
Sound insulation
Building façade
Noise mapping
Noise control criteria
Action plans

A B S T R A C T

The EU Directive 49 urges countries to prepare the strategic noise maps and the action plans for the agglomerations along major transportation routes and major industrial premises. Environmental engineers, town planners and architects are involved in preparation of action plans in which sound insulation of buildings are to be considered. This article describes a model to determine the required insulation performances for buildings' external elements by using strategic noise maps. The model employs certain categorization for buildings in relation to indoor noise criteria and for insulation values to be assigned on building facades. A calculation procedure is integrated with the outputs of a noise mapping software to obtain the required noise reduction indexes in terms of both spectral values and the single-number ratings, i.e. "weighted- standardized level differences". Calculated results are displayed graphically to be able to observe variation of insulation requirement throughout the surface exposed to noise source. Insulation map as a visual tool can facilitate building noise control and can be utilized in preparation of building specifications prior to construction phase and in developing the insulation codes by local administrations. Implementation of the model for two sample buildings located at different environments are explained in the article.

1. Introduction

Sound insulation design for buildings is an important task in environmental noise control. After noise mapping was obliged by EU Directive 49 (END) prior to developing noise control strategies, environmental engineers, town planners, architects, builders etc all have to be involved with the action plans in which sound insulation performances of buildings should be taken into account [1]. Since the investigations have evidenced the severity of noise impact caused by all types of noise sources, not only the transportation systems, i.e. motorways, railways and aircrafts, but also industrial premises, mechanical services, amplified music as well as various indoor noise sources have to be dealt with in the action plans [2]. Buildings can be protected from excessive noises by means of technical solutions, planning and regulations within the general concept of "environmental noise management" [1,3].

END proposed the "most exposed façade" and the "quiet façade" to be indicated on noise maps. Quiet façade is the façade with noise level difference more than 20 dB from the noisiest façade or simply "the facade facing toward the zone exceeding the specified noise limit" [4]. This is one of the issue being discussed internationally, however even the quiet facades need certain amount of insulation for themselves due to possible increase in noise levels.

Determination of acoustical performance for building facades depends on external noise data representing both actual and future conditions. Architects, acoustic consultants, building contractors and those preparing building specifications, need ready-to-use data for designing the building external elements. Therefore description of insulation degrees and their transformation into the design language are important for their use. An approach to solve this problem is explained in this article.

2. Noise maps and sound insulation

As known, the noise maps are defined as digital and visual model of a physical environment including noise sources and their major objective is to constitute a basis for noise control action plans [5,6]. Two types of noise maps have been proposed in END: "Noise map" for a specific environmental noise source such as transportation or industry and "Strategic noise map" combining all the noise sources to investigate the total impact in the environment.

2.1. Noise mapping objectives and methodology

Noise maps are prepared for the following purposes:

- To investigate noise conditions whether existing noise limits are exceeded or not
- To obtain noise zones with respect to noise levels and "hot spots"
- To determine the population affected by various noise levels

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doi:10.1016/j.buildenv.2011.07.006

- To assess the noise levels on the facades of sensitive buildings
- For new land use planning and to determine building configurations in noisy areas
- To investigate noisy activities (temporary or permanent)
- To compare calculated and measured noise levels
- To design barriers and cost analysis
- To develop noise control strategies and action plans
- To investigate the performance of a measure (e.g. noise barriers) by comparing the “before” and “after” maps
- To evaluate the effects of alternative solutions against environmental noise
- To obtain data for the field surveys (i.e. noise/dose relationships in order to derive noise control criteria or limits)
- To make comparisons between those prepared for other pollutions (e.g. air pollution)
- To give information for community and to provide data for decision makers
- To assess the economical losses due to noise pollution and the reductions in property values (e.g. 1 dB increase in noise level corresponds to 1% decrease in house rents).

In addition to above purposes, the noise maps can be used to determine the required sound insulations for buildings. This subject will be explained below.

2.1.1. Methodology of noise maps in built up areas

Noise contours which are depicted on geometrical and physical map of a specific environment, are obtained by using the prediction models for different noise sources, i.e. ECAC model for airports, ISO 9613 for industrial premises, RMRS model for railways and NMPB and Harmonoise models for road traffic [7–11]. Noise maps generally indicate yearly average levels or noise levels in favorable conditions thus implying the worst cases. END recommends L_{Aeq} based noise descriptors (L_{day}, $L_{evening}$, L_{night}) and L_{den} with some weightings according to time of the day. An additional document (WG-AEN guide) has been published to predict the uncertainties of calculated results for reproducibility and verification of noise maps [12].

As widely known, methodology of noise mapping in built-up areas, involves: a. Data acquiring, b. Criteria establishment, c. Calculation of noise levels on a grid system, d. Displaying noise contours on the physical-environment models. The other factors to be considered during mapping activity are: cost of work, software to be employed, capacity of computers, data availability, available personnel, technical skill, time limit etc.

2.1.2. Input data for noise mapping

Strategic noise maps require detailed information about the noise sources, physical environment and population in the community prior to modeling the environment and acoustical conditions. These are summarized in Table 1.

2.1.3. Calculation of noise levels

Various theoretical or empirical models can be performed in computations by taking into account reflection, absorption, scattering and diffraction of sound waves during propagation of sound in environment. The noise levels are calculated at each grid point

Table 1
Summary of the input data for noise mapping and evaluations.

Data	Parameters				Acoustical data
Sources & emissions	Road traffic	Railway traffic	Aircraft traffic	Industry	
	Road geometry Gradient Curvatures Surface cover Speed Volume of traffic Heavy vehicle percentage Type of traffic flow Traffic lights	Number and types of trains Average speed Sirens Railway structure (in cuttings, level or elevated) Type of rails, ballasts& ties Bridge structures	Airport plan Runway configuration Flight operations (daily, yearly etc.) Types of aircrafts	Layout plan for open air activities Factory buildings Manufacturing process Indoor -outdoor equipment Operation modes (hourly, daily, weekly)	Sound power levels in L_w, dBA and the spectral values Source directivity Reference sound pressure levels with temporal and spectral variations For complex sources: contributions from individual parts
Physical environment	Ground cover and woodland	Buildings	Obstacles	Meteorological factors	
	Type of surface (sound absorption coefficient) Width of surface under sound path Surface area Configuration of different surface types Type of plants Configuration of trees (deciduous, evergreen, etc)	Location Geometry Façade shape (balconies etc.) Number of floors (or total height) Function Façade cover (sound reflection properties)	Natural (topography) or built barriers Location (distance from source) Thickness Length Height Surface type Top profile of screens Surface cover Constructional material	Wind gradient Temperature gradient Humidity (air absorption) (Short, mid and long term average values) Favorable conditions increasing noise levels	Effects of physical factors on immission values caused by wave divergence absorption, diffraction, refraction, scattering of sound Total sound attenuation
Demographic	Land use information and applicable noise limits	Population structure	Building and usage	Future plans about area	
	Urban residential Suburban& rural Healthcare buildings Educational buildings Administrative area Shopping centers Industrial and mixed zones Touristic area (hotels, motels) Recreational and entertainment area Parks& cemeteries	Total population Number of residents for each building Social, educational and economical characteristics of community Seasonal activities (in touristic areas),	Sensitivity to noise Indoor noise limits Times of occupation (Daily, yearly) Open/closed windows Existence of AC equipment Indoor noise sources (background noises) Layout of rooms Building construction	On-going and future constructions Extension or modification of noise sources, Existing noise action plans	Noise -dose and response relationships for various types of land uses Noise levels and performance effects *Outputs from noise maps:* Number of people and buildings exposed to various noise levels Number of buildings having quiet facades