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METHOD FOR CALCULATION OF NOISE FIELDS IN MULTIPLE-BUILDING ENVIRONMENT

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Key words: *Noise mapping, urban noise*

Abstract: *The paper presents a method that may be used for noise mapping and calculation of noise fields in the environments that contains multiple buildings. While the international standard for calculation of noise levels ISO 9613-2 proposes a method for attenuation of sound by housings, it is not suitable for application in cases where distances between source of noise and endangered area are close to distances between buildings, especially in the case when distribution of buildings is not regular. The proposed method enables calculation of noise levels for each specific case by calculating effects of diffraction of sound over each of the building's roofs and around corners of the buildings. However, the proposed does not take in the account reflection of the emitted sound during propagation.*

1. INTRODUCTION

Environmental noise is defined as unwanted outdoor sound caused by human activities, including noise emitted by means of transport, industrial and recreational activities [1]. In 1972, the World Health Organization (WHO) classified noise as a pollution that can significantly affects human health and productivity, causing stress, sleep disturbance, cardiovascular problems, etc., as it has been shown in many studies during past decades [2-4]. Moreover, the environmental noise pollution has a great impact on real estate prices [5].

According to the WHO guidelines, in order to prevent adverse health effects from night noise, noise level should not exceed 30 dB(A) in bedrooms during the night, while it should be less than 40 dB(A) outside of bedrooms. Also, noise level should be less than 35 dB(A) in classrooms in order to allow good teaching and learning conditions.

Serbian National Sustainable Development Strategy [6], which was adopted in 2008, recognizes noise as a cause of population health risks in settlements of the Republic of Serbia. In accordance with this strategy, Law on Protection from Noise Pollution, Regulation on Noise Pollution Indicators, and series of rulebooks and standards have been adopted for the purpose of harmonizing the national noise regulations with the Environmental Noise Directive (2002/49/EC) [7]. According to that directive, Member States are obliged to produce noise maps every five years for all agglomerations, major roads and major railways. Furthermore, based on results of noise mapping, the competent authorities have to draw up action plans in order to manage noise issues and effects.

In course of the project "Development of methodologies and means for noise protection of urban environment" [8], funded by Serbian Ministry of Education and Science, Faculty of Mechanical and Civil Engineering in Kraljevo has developed a software tool for local noise mapping and prediction according to ISO 9613-2 standard [9]. ISO 9613-2 standard specifies a method for calculation of sound attenuation during outdoors propagation caused by geometrical divergence, atmospheric absorption, reflection from surfaces and screening by obstacles. The method for estimating approximate value of sound attenuation during propagation through foliage, industrial sites and built-up region of houses is also specified by the ISO 9613-2 standard.

This paper presents a method for calculation of noise levels in environment that consists of multiple buildings.The proposed method enables more precise noise prediction in comparison with method defined by ISO 9613-2 standard for estimation of the noise field in housing areas.

2. ISO 9613-2 STANDARD

According to ISO 9613-2, when source and/or receiver are positioned in a built-up region of houses, an approximate value of the attenuation due to screening by the houses and reflections from the house facades may be estimated using the equation

$$A_{house} = 0.1 \cdot B \cdot d_b, \tag{1}$$

where$B$ represents the buildings density along the sound path and$d_b$stands for the total path length through the built-up region of houses. The density of buildings $B$is defined as the ratio of the total plan area of the houses divided by the total ground area, including that covered by the houses. The length of the sound path through the built-up area $d_b$is roughly estimated usingan arc in vertical plane with 5 km radius that joins noise source and receiver (see Figure 1).The length d_b is calculated as the sum of the lengths of parts of the arc that pass through the built-up area in vicinity of the source (d_1) and the receiver (d_2).

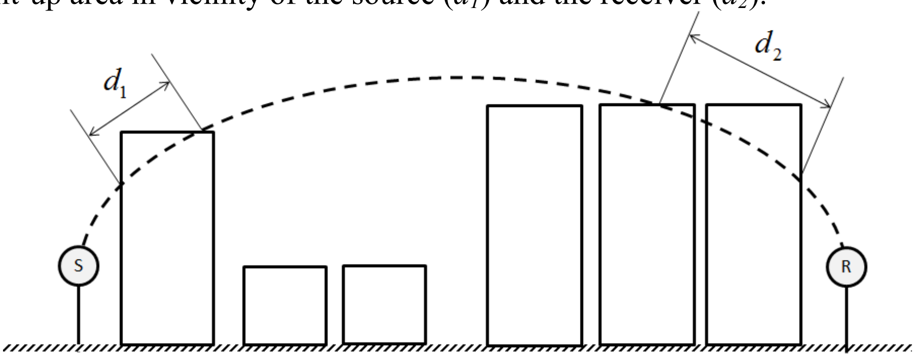

Fig.1

In the specific, but quite usual case of traffic noise of a road or railway line propagating through well-defined rows of nearby buildings, the calculated attenuation should be decreased for the amount

$$\Delta A_{house} = -10 \cdot \log\left(1 - p/100\right) \left[dB\right], \tag{2}$$

where p represents the percentage of the length of the facades relative to the total length of the nearby road or railway. The percentage p should be smaller than 90%, and if it has the higher value, then the attenuation should be calculated is if the array of buildings represents a barrier at the same position with the height equal to the mean height of the buildings.

However, in the opposite limiting case of a small source with a direct, unobstructed, line-of-sight to the receiver down a corridor gap between the housing structures, the attenuation due to the screening by the housing should not be considered. Furthermore, the standard ISO 9613-2 recognizes that the screening by the houses may be in many other cases compensated by the propagation between the houses and by reflection form other houses in the vicinity. Therefore, in many practical cases this combined effect of screening and reflections has to be estimated by applying procedures for calculation of effects of barriers and reflective surfaces.

3. PROPOSED METHOD

The value of the A_{house} attenuation may be estimated more precisely by modeling sound reflection from the facades, as well as sound diffraction over buildings' rooftops and around the buildings' corners. For the purpose of reflection modeling, a building should be represented by several reflective surfaces, so that each reflective surface corresponds to one of the building facade walls. Sound reflections from reflective surfaces are computed by using the image source model defined by ISO 9613-2 standard.

When a building obstructs acoustical line-of-sight between sound source and receiver, the sound waves emitted by the source undergo diffraction 1) over the building's rooftop, and 2) around the corners of the building.

Modeling of diffraction over building rooftops may be performed if each building facade wall is represented by a single barrier.The attenuation due to the diffraction over building rooftops may be then calculates as attenuation due to diffraction over the top edges of the series of barriers, as defined by ISO 9613-2 standard.

Modeling of diffraction around buildings' corners may be performed if each building is represented by one or more quadrilateral prisms. Each of the prisms should further be represented by two thin barriers at prism cross sections, whose projections in the xy-plane correspond to diagonals of the prism base. Finally, the attenuation due to the diffraction around buildings' corners may be calculated using method for calculation of the attenuation due to diffraction around vertical edges of the barrier, defined by ISO 9613-2 standard.

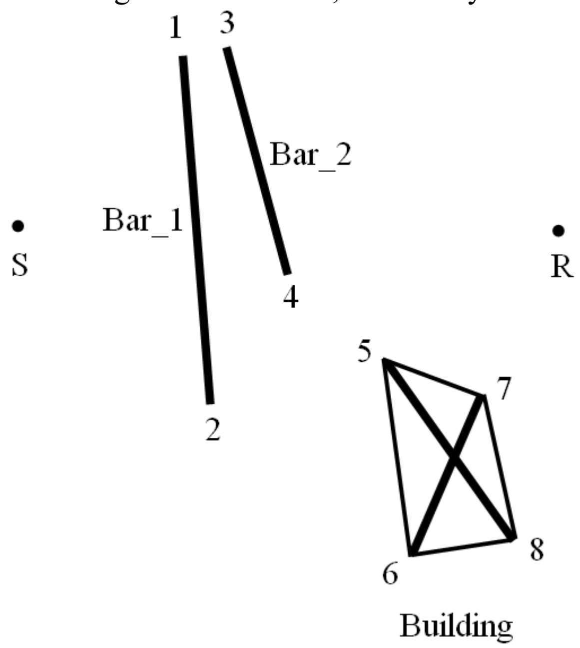

Fig.2

When several barriers are positioned between sound source S and receiver point R, in order to determine all significant diffraction paths between the source and receiver, diffraction points should be obtained by projection of the SR line segment to barriers edges. All diffraction points should be numbered sequentially from 1 to n_{diff}, after they have been sorted in ascending order according to distance between their projections on the SR segment and position of the sound source S. A logical (binary) propagation matrix C should be defined in such a way that each matrix element c_{ij} denotes the possibility of direct sound propagation from the point i to point j, where i corresponds to either the source point or to diffraction point i-1, depending on whether i has value 1 or if it is greater than 1, while j corresponds to diffraction point j or to receiver point, depending on whether $j \leq n_{diff}$ or $j = n_{diff} + 1$. If $j=i-1$, c_{ij}matrix element has value 0. Also, when two diffraction points belong to the same barrier, corresponding matrix element has value 0. Since sound waves, which, after diffraction, return toward sound source, should not be considered, c_{ij}=0 for each $j<i$. After sound diffraction around the point i, which is connected via an unobstructed line–of–sight with receiver point ($c_{i+1,ndiff+1} = 1$), only sound that propagates directly to the receiver point is considered, so, when $c_{i+1,ndiff+1} = 1$, for each $j>i$ ($j \neq n_{diff} + 1$) $c_{i+1,j}$ element has value 0. If an unobstructed line–of–sight connects sound source and diffraction point j, only direct sound waves, which arrive from the source to diffraction point j without any diffraction, are considered. Therefore, if c_{1j}=1, for $i \leq j$, and $i \neq 1$, matrix element c_{ij}has value 0.

For the example given in the Figure 2, when two barriers, denoted with Bar_1 and Bar_2, as well as one building, obstruct the line-of-sight between sound source and receiver, sound reaches receiver point due to diffraction around barriers and building, which is represented by two diagonal barriers. Diffraction points are marked with numbers 1 to 8. In order to determine all significant diffraction paths between source S and receiver R for the given example, the propagation matrix C is given by the following values:

$$C = \begin{bmatrix} 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}.$$

As sound source is connected via unobstructed line-of-sight only with diffraction points 1 and 2, first and second elements of the matrix first row have value 1, while all the other elements of this row have value 0. Since sound barrier Bar_2 obstructs line-of-sight between point 1 and receiver, only sound waves that undergo diffraction around vertical edges of the barrier Bar_2, or around the building edge 6, can reach receiver point. Therefore, only third, fourth and sixth elements of the second row of the matrix C are equal 1. Since line-of-sight connects receiver point and diffraction point i, $i \in \{2, 3, 4, 5, 7, 8\}$, the ninth element of the row i+1 is equal 1. As the remaining elements of corresponding rows have value 0, the sound waves which, after diffraction, return toward sound source are not considered, as well as the sound waves that, after diffraction around vertical edges that are connected with the receiver point via line–of–sight, undergo additional diffraction before reaching the receiver point.

Based on the matrix C, all significant sound propagation paths may be determined. For the example given in Figure 2, sound waves may travel from the sound source S to receiver point R along following paths:

- S → 1→ 3 → R
- S → 1 → 4 → R
- S → 1 → 6 → 8 → R
- S → 2 → R

For each of the propagation paths attenuation due to geometrical divergence, atmospheric absorption, ground effect and diffraction around vertical edges should be calculated in accordance with ISO 9613-2 standard.

4. CONCLUSION

As noise pollution significantly affects human health and productivity, measurement and prediction of environment noise in the urban areas areof great importance for assessment of population vulnerability to noise, as well as for development of methodologies and means for noise protection. Sound propagation in the urban environment is complex due to multiple reflections and diffraction. Since ISO 9613-2 standard defines method for estimation of approximate values of noise levels in multiple-building environment, in order to obtain more precise noise predictions, in this paper is presented method for modeling of reflections from the facades of the buildings, as well as sound diffraction over buildings' rooftops and around the buildings' corners. The procedure for determining of all significant diffraction paths between sound source and receiver is explained in this paper. The presented method for calculation of noise fields in multiple-buildings environment should be expanded by including propagation paths with combined effects of diffraction and reflection.

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REFERENCES

[1] Department of Environment Heritage and Local Government, Ireland, 2006. Statutory Instrument Number 140 of 2006, Environmental Noise Regulations.

[2] Ohrstrom, E.; Rylander, R. "Sleep disturbance by road traffic noise - A laboratory study on number of noise events". Journal of Sound and Vibration, vol. 143, no. 1, pp. 93–101, 1990.

[3] Fyhri, A.; Klboe, R. "Road traffic noise, sensitivity, annoyance and self-reported health - A structural equation model exercise". Environment International, vol. 35, no. 1, pp. 91-97, 2009.

[4] Pirreera, S.; Valck, E. D.; Cluydts, R. "Nocturnal road traffic noise: A review on its assessment and consequences on sleep and health". Environment International, vol. 36, no. 5, pp. 492–498, 2010.

[5] Theebe, M. A. "Planes, trains, and automobiles: The impact of traffic noise on house prices". Journal of Real Estate Finance and Economics, vol. 28, no. 2, pp. 209–234, 2004.

[6] National strategy of sustainable development, Government of Republic of Serbia, Belgrade 2008

[7] Directive 2002/49/EC of the European Parliament and the Council of June 2002, Official Journal of the European Communities, 2002.

[8] M.Kolarević, Z.Šoškić, Z.Petrović, B.Radičević, "Noise Protection in Urban Environment-Description of a Project", Mechanics, Transport Communications, No. 3, p. IV-69/IV-77 (2011)

[9] ISO 9613-2:1996, Acoustics - Attenuation of sound during propagation outdoors – Part 2: General method of calculation

МЕТОД ЗА ИЗЧИСЛЯВАНЕ НА НИВАТА НА ШУМ В ГЪСТО НАСЕЛЕНИ РАЙОНИ

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Ключови думи: *планиране на шума, градски шум*

Резюме: *Докладът има за цел да представи метод за планиране и изчисляване на нивата на шум в гъсто населени райони с множество сгради. Докато международният стандарт за изчисляване на нивата на шум ISO 9613-2 предлага модел за смекчаване на шума от жилищата, този метод обаче не е подходящ да бъде приложен в случаи, където разстоянията между източника на шум и застрашената зона се намират в близост до сгради, които не са разположени правилно една от друга. Предложеният от авторите модел позволява да се изчислят нивата на шум за всеки конкретен случай, като се определят и ефектите от дифракцията на звука по пкривите и около ъглите на сградите. За съжаление, предложеният модел не взема предвид отражението на шума при неговото разпространение.*