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Practical analysis of the influence of basic meteorological phenomena on the long-term noise level

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Current regulations on the prognosis of the acoustic climate outdoors require that meteorological conditions should be integrated into long-term noise level calculations.
The analysis of individual processes, conducted in this study, greatly expands the cognitive scope of application and technical methods commonly used.
In particular, the proposed simple mathematical description of the relationship between geometric parameters, such as the location of the receiver point in relation to a linear noise source, constituted by the road, and the influence of meteorological factors, contained in the parameter P, is consistent with the initial function equation.
The conducted numerical calculations establish the relationships between the geometry of the system: noise source–receiver point, meteorological influences and the noise level (noise level increase).

1 Introduction

Current regulations on the prognosis of the acoustic climate outdoors require that meteorological conditions should be integrated into long-term noise level calculations. Meteorological factors are indeed used in the NMPB-96 method, recommended by Directive 49/2002/CE [1] for road-generated noise, while the Mithra french software, based, *inter alia*, on the calculation algorithm of this method, is fully adjusted to simulation calculations of long-term noise that also examine meteorological phenomena [2,3].

The impact of meteorological conditions on the noise level was analysed using simulation calculations performed with the Mithra software. The aim of the analysis was to determine the relationship between the value of these influences and the distance between the receiver point and the noise source and its height above the ground.

2 Entry data for simulation calculations

A multi-lane carriageway running across absorptive areas, such as fields or meadows, whose acoustic power was assumed to be constant was assumed to be the noise source in simulation calculations. Its distance from the built-up area varied. A number of its locations in relation to the built-up area ranging between 200m and 4 000 m were considered.

The built-up area consisted of a row of 11-storey buildings ca. 600 m long. The ground floor height and the floor height were accepted to be 3.5 m and 3.0 m, respectively. Calculations were performed for various meteorological conditions: from P=0 (homogenous conditions) to P=1.0, increasing by every 0.1. The receiver point was located 2 m away from the façade at varying heights: from the lowest point positioned at 5 m to the highest point at 27.5 m, increasing by 2.5 m, which corresponds to the median position of each successive storey, from first floor to tenth floor.

The diagram of the calculation system is given in Fig. 1.

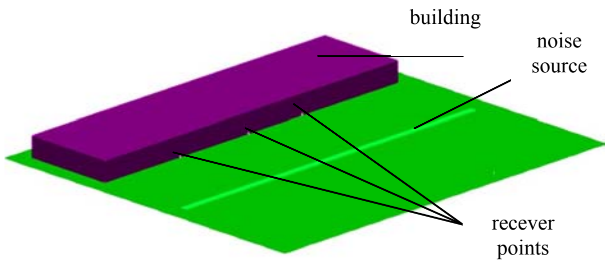
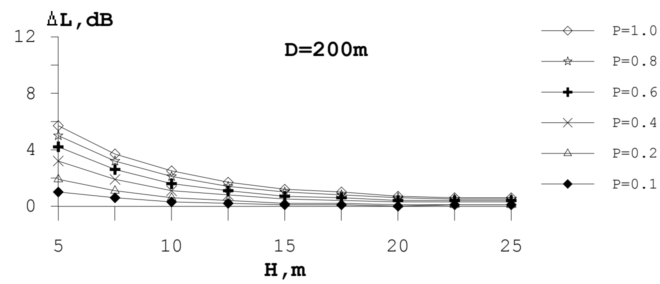


Fig. 1. Diagram of simulation calculations

3 Simulation calculations

Relationships between geometric parameters (H – height above the ground of the receiver point, D – source-to-receiver distance) and the parameter P of the influence of meteorological conditions for selected distances D are presented in figures 2 ÷ 5.



.Fig.2 Influence of the meteorological conditions on the noise level increase for the distance D=200m

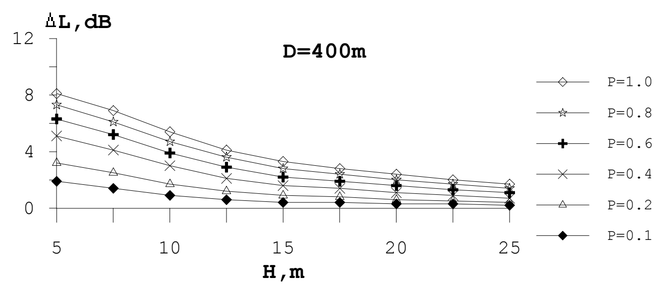


Fig. 3 Influence of the meteorological conditions on the noise level increase for D=400m

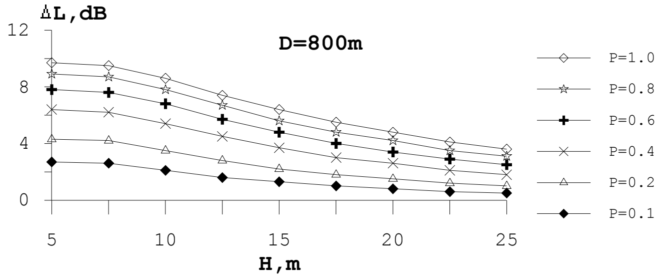


Fig. 4 Influence of the meteorological conditions on the noise level increase for D=800m

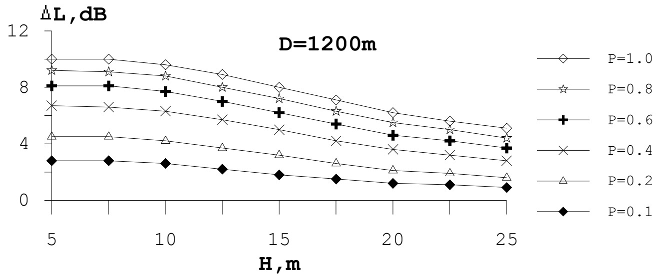


Fig. 5 Influence of the meteorological conditions on the noise level increase for D=1200m

4 The influence of the receiver point height and source distance

The influence of meteorological conditions, expressed by the parameter P, varies depending on the height of the receiver point near the façade and the distance from source to receiver point. The noise level difference (ΔL) for selected cases, related to homogenous conditions (P=0) as a function of height above the ground and the source-to-receiver distance, is given in figures 6 ÷ 10. Influences of meteorological conditions vary for different positions of the receiver point on the façade in at distances ranging between 200m and 4 000m. Their values increase as the distance from the source increases, and are the greatest at a distance of ca. 1 200 m. A further increase in the distance from the source causes gradual attenuation of this influence. At the same time, these influences depend on height above the ground of the receiver point. For the distances up to 1 200 m, the greatest values are recorded at lower storeys (5-10m), while the greatest values occur in points located higher for distances above 2 000 m (from 12.5m to 20m). A certain decrease in this influence is noted for H>20 m although it still remains quite high. It should be remembered, however, that the total influence of the road on the acoustic field will be significantly lower for such long distances from a built-up area. Therefore, further practical analysis of the relationships between the distance from the source, receiver point height and the value of parameter P is limited to the area situated no more than 1 200 m away from the source.

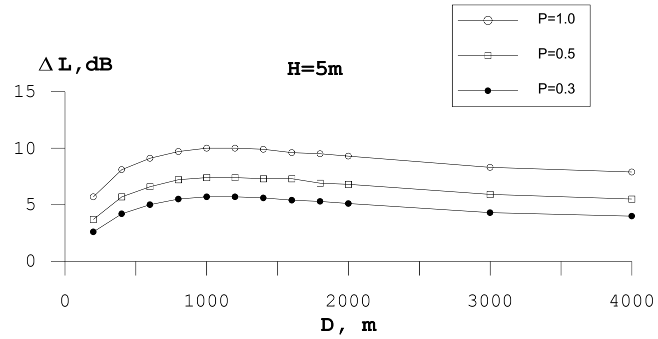


Fig. 6 Influence of the source distance on the long-term noise increase for H=5m

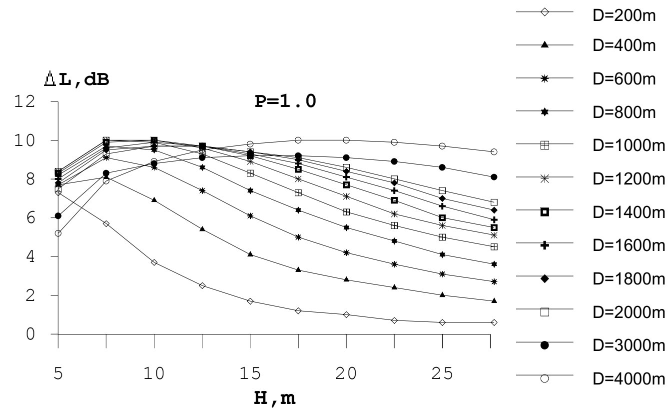


Fig. 7 Influence of the source distance on the long-term noise increase in relation to receiver point height for P=1.0

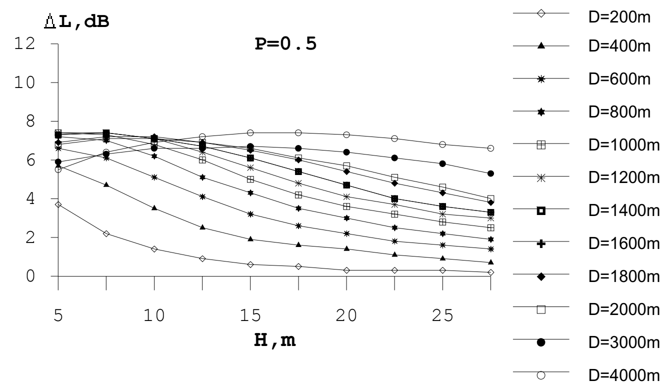


Fig. 8 Influence of the source distance on the long-term noise increase in relation to receiver point height for P=0.5

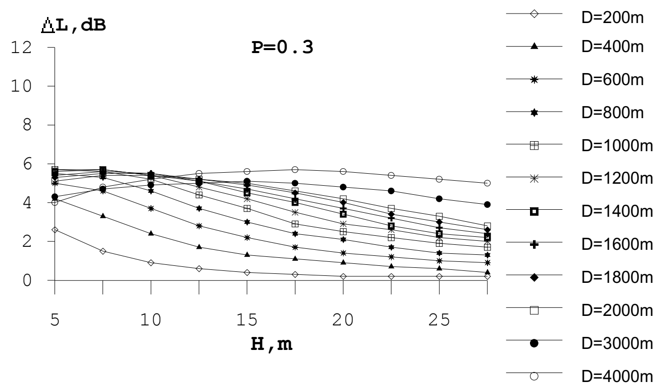


Fig. 9 Influence of the source distance on the long-term noise increase in relation to receiver point height for P=0.3

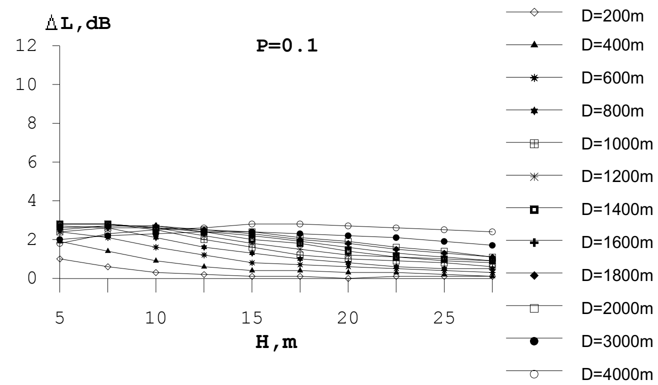


Fig. 10 Influence of the source distance on the long-term noise increase in relation to receiver point height for P=0.1

4.1 The influence of receiver point height

As discussed in the previous Chapters, changes in meteorological parameters affect sound propagation speed in air. The vertical profile of sound celerity is the resultant sum of aerodynamic and thermal influences on the speed value [4]. It may be assumed that sound propagation is linear in homogenous conditions and that it changes exponentially with height in favourable conditions as a result of the influence of thermal effects and the curvilinear influence of the wind, similar to its exponential influence. For the former, noise level changes may be described by the following function [4]:

$$d(\Delta L) = \left[f(H)^n \right] df(H) \qquad (1)$$

and for wind influence:

$$d(\Delta L) = e^{f(H)} f'(H) dH \qquad (2)$$

The total impact of both factors, described by the above equations, gives a general relationship:

$$\Delta L = K H^n e^{aH} \qquad (3)$$

The curves of meteorological influences on the sound level at different heights, based on the simulation method and equation (3), are presented graphically in Fig. 11.

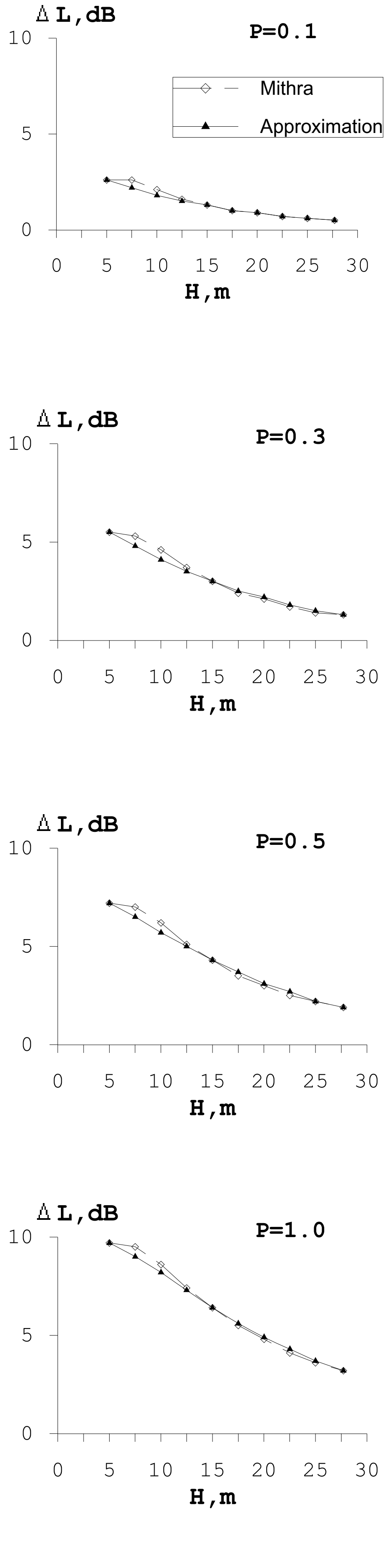


Fig. 11 Influence of the receiver point height on the noise increase caused by meteorological influence for noise source distance 800m

The analytic method was used to determine the parameter in equation (3) for various distances from the noise source by linearising the simulation results in the co-ordinate system: $\lg(H_{n-1} - H_n)$; $\lg(\Delta L_{n-1} - \Delta L_n)$. The consistence of the simulation calculation results with those of the accepted mathematical model for the equation ΔL=f(H) is characterised by a high correlation coefficient ranging between 0.96 and 0.99.

4.2 The influence of source distance on the noise level increase on the façade

To examine the influence of the source distance on the long-term noise level increase on façades, its dependence on parameter P, that is the occurrence frequency of favourable conditions, should be analysed.

For the range of distances between 200 m and 1 200 m, the noise increase on a façade ΔL may be described with the accuracy sufficient for the technical assessment from the following equation [4]:

$$\Delta L = A \ln D - B \tag{4}$$

or

$$D = e^{\frac{\Delta L + B}{A}} \tag{5}$$

Constants A and B are related with the parameter P as a function. The constant B is negative and is the reference level for ΔL. The values of parameters A and B show that they are related as a function by an exponential relationship with the parameter P. This relationship may be written in a general form as:

$$A = kP^K \tag{6}$$

$$B = k' P^{K'} \tag{7}$$

For the values of A and B determined from equation (4), constant parameters k and k' as well as K and K', occurring in these equations, may be determined based on linearisation by finding the logarithm of equations (6) and (7). A high correlation coefficient ranging between 0.97 and 0.99 was obtained for the analysed values ΔL=f(D).

5 Conclusion

The numerical calculations (computer simulations) performed in the study are a significant contribution to the current acoustic research. They were crucial in conducting an application and technical analysis of noise propagation conditions and identifying their possible uses in the assessment of the study results. The analysis establishes interconnections between such parameters as the distance between the noise source and the receiver, height of the sound receiver point over the ground and the influence of meteorological conditions on the effective noise level in the form of simple equations.

References

[1] Directive 2002/49/EC of European Parliament and of the Council of 25 June 2002 relating to the asessment and management of environmental noise

[2] Bruit des infrastructures routieres: méthode de cacul incluant les effets météorologiques. NMPB – routes – 96, joint study. CERTU, CSTB, LCPC, SETRA, (1997)

[3] B.Lebiedowska, „Hałas wokół autostrad – metody prognozowania, Wydawnictwo Politechniki Łódzkiej, Łódź (1998)

[4] B.Lebiedowska, „Pameters of noise Propagation Outdoors – Parametry propagaji hałasu w terenach otwartych, Ed. Akademia Humanistyczna im.A.Gieysztora, Pułtusk (2007).