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INFLUENCE OF METEOROLOGICAL CONDITIONS ON EFFECTIVENESS OF ACOUSTIC SCREENS – MEASUREMENTS AND COMPUTATIONS

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The paper presents the results of simulation and field studies of the effectiveness of road acoustic screens. In the simulation studies the influence of the declared weather conditions on the predicted acoustic screen effectiveness determined for different field conditions by different methods is analyzed. A comparative analysis of the results of screen effectiveness computations and measurements for three real systems of acoustic screens located by national roads in urbanized areas for different times of day is made.

Keywords: acoustic screens, meteorological conditions.

1. Introduction

As a result of the increasing road traffic intensity increasingly larger areas come within reach of road noise. For dual carriageways or motorways, with a traffic volume of $30\ldots50$ thousand vehicles per day, the range of the admissible noise in the night-time amounts over 500 m. At such large distances the weather conditions significantly affect the propagation conditions and so the effectiveness of acoustic screens [1, 2]. The state-of-the-art methods of computing outdoor noise allow one to take into account the influence of weather conditions. However, the ways in which it is done and in which the input parameters are defined differ.

The aim of this research was to analyze the influence of the assumed weather conditions on the results of computations of road acoustic screen effectiveness and to compare the computation results with those of in situ measurements. The uncertainty of acoustic screen measurement and computation results is a crucial problem in practical applications since it determines decisions about acoustic screen design parameters and the follow-up assessment.

2. Methods of research

Professional software SoundPlan v.6.4 and two computing methods: the NMPB road noise calculation method, recommended by the noise directive for use in the UE for computations of strategic acoustic maps and the general method of calculation of sound attenuation during propagation outdoors, described in standard PN-ISO 9613-2, were used. The NMPB method describes a noise source model and a model of sound propagation. In the case of standard PN-ISO 9613-2, the road was modelled as a linear noise source having the same parameters as in NMPB.

In the analysis of the influence of weather conditions on sound propagation one distinguishes: favourable conditions, unfavourable conditions and homogenous conditions. Favourable conditions are considered to be conditions conducive to sound propagation from the source to the observer, i.e. wind consistent with the direction of sound propagation and a temperature gradient as a function of elevation, causing sound rays to curve downwards. Homogenous conditions correspond to a situation when propagation proceeds along straight lines (no wind, air temperature constant as a function of elevation). Homogenous conditions make it possible to determine the boundary between favourable and unfavourable conditions.

In NMPB the input parameters describing weather conditions are: parameter p expressing the percentage ratio of favourable to homogenous conditions and mean air temperature and relative humidity. For a given area, parameter p is calculated from averages from many years of meteorological observations. In the case of strategic map computations, when there are no proper data, it is recommended to assume: $p = 50\%$ for daytime, $p = 75\%$ for evening time and $p = 100\%$ for nighttime. The relations in ISO9613 describe sound attenuation for propagation in favourable conditions. The influence of other (real) meteorological conditions is taken into account through meteorological correction C_{met}. For large distances between the sound source and the observer one can assume:

$$C_{\text{met}} = C_o = 10\log\left(P_f + (1 - P_f)\cdot 10^{-0.1\Delta L}\right), \tag{1}$$

where P_f – the frequency of occurrence of favourable conditions, ΔL – the difference in the sound level between favourable and unfavourable conditions. When no data are available, $\Delta L = 12$ dB is assumed.

3. Simulation study

The simulation studies focused on the influence of weather conditions on the predicted effectiveness of acoustic screens in different terrain conditions [3]. A straight stretch of dual carriageway with overall width $w = 26$ m and constant traffic conditions, situated in flat terrain: a) at ground level, b) on an embankment and c) in an excavation was adopted for the studies. An absorbing acoustic screen was located at a distance of 2.5 m from the edge of the roadway or excavation. The length of the screen was such that the influence of finite screen length could be neglected.

Changes in screen effectiveness as a function of distance (d) and the height (h_o) of observer for different acoustic screen heights (h_e) depending on the weather conditions and the acoustic properties of the ground surface were investigated. The range of the investigated parameters was: distance $d = 25 \ldots 800$ m, at a step of 50 m for $d < 300$ m and 100 m for $d > 300$; height $h_o = 2$ m, $4 \ldots 32$ m at a step of 4 m; screen height $h_e = 2 \ldots 12$ m at a step of 2 m; ground surface: $G = 0$ (reflecting), $G = 0.5$, $G = 1$ (absorbing); embankment height $h_n = 1, 3, 5$ m; excavation depth $h_w = 1, 3, 5$ m, embankment inclination angle – 45%. Computations were performed in octave frequency bands, assuming road noise spectrum according to EN 1793-3:1997. The studies were carried out for typical parameters describing weather conditions: NMPB: $p = 0, 50, 75$ and 100% and ISO9613-2: C_o determined for $P_f = 0, 50, 75$ and 100% and $\Delta L = 12$ dB, as well as for the meteorological conditions typical for the city of Wrocław [4]. Favourable conditions correspond to $p = 100\%$ in NMPB and $P_f = 100\%$ in ISO9613 while neutral conditions correspond to $p = 0\%$ in NMPB and $P_f = 50\%$ in ISO9613.

The results of the simulation studies are presented in the form of graphs illustrating changes in screening effectiveness ΔL_{Ae} as a function of distance for a selected constant parameter (e.g. Fig. 1).

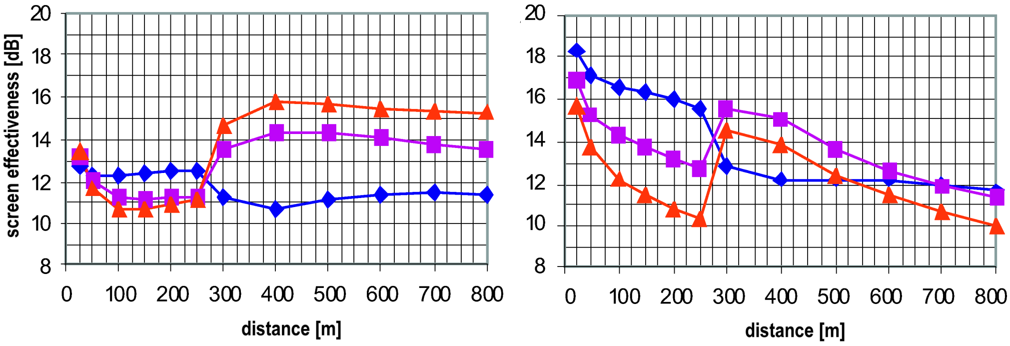

Fig. 1. Calculated ΔL_{Ae} acc. to NMPB and ISO9613 for $G = 0.5$ and 1; $h_e = 6$ m, $h_o = 2$ m.

4. Comparative studies

The aim of the studies was to compare the acoustic screening effectiveness values computed and measured for different situations at different daytimes. The effectiveness of the acoustic screens was measured in situ by a modified indirect method (based on PN-ISO 10847) using a natural noise source (road traffic) [5, 6]. According to the above standard, the principle of measurement allows one to determine the noise level (L') for a situation without a screen on the basis of measurements made in a measuring point equivalent to the investigated point. The equivalence should cover the conditions of sound emission and propagation. No time when the measurements should be performed is specified in the standard. For practical reasons such measurements are performed mainly at daytime. In real terrain conditions it is difficult to determine the equivalent measuring point and the result of such evaluation of L' is loaded with high uncertainty. In the investigations it was assumed that sound level (L'_i) in the *i*-th point before screen installation is to be determined on the basis of measurements carried out in reference point (L_0) and from the relation describing sound propagation in urbanized space:

$$L'_i = L_0 - 10\log\left(\frac{d_i}{d_0}\right) - \sum_i A_i, \tag{2}$$

where d_i – the distance between the source and the *i*-th observation point, d_0 – the distance between the source and the reference point, $\sum A_i$ – additional sound suppression during propagation.

The field and simulation studies were made for three systems of screens of various types, located by national roads in urbanized areas:

1) a "green wall" screen, 500 m long and $4\dots6$ m high, located at a distance of 1.5 m from the roadway of the dual carriageway,
2) a system of reflecting transparent screens, about 120 m long and 4 m high, located on both sides of the road,
3) a reflecting screen with gaps, having a total length of 350 m and a height of 2.2 m, located at a distance of 8 m from the road.

Depending on the terrain conditions, noise as a function of distance from the screen was measured on the sections located in the screen's central part and near its ends as well as along the screen. In order to determine if the time of day affects the results, the investigations were carried out at three different times of day: morning hours from 5.00 to 7.00, afternoon hours from 15.00 to 17.00 and night hours from 22.00 to 0.00. Three elementary measurements were performed for each time, assuming $T = 8\dots15$ min depending on the traffic intensity. For selected measuring points the measurements were repeated three times on consecutive days. The range of measured distance was from 10 m to 140 m behind the screen (because of neighbourhood noise). $\sum A_i$ was calculated from relation (2) by the calculator method, taking into account sound absorption in air, sound attenuation by the ground and by buildings in accordance with ISO 9613.

One worked out computational models of examined situations using the SoundPlan program. Variant computations were performed using NMPB and ISO-9613, in which the influence of the input parameters, such as ground surface properties or number of reflections N, on the computation error was analyzed. For situations (1) and (2) and daytime, weather conditions were assumed according to the data for the investigated region whereas for nighttime $p = 100\%$ was assumed [3]. In the case of situation (3), because of the lack of data, $p = 50\%$ and $p = 100\%$ were assumed for respectively daytime and nighttime.

5. Results and conclusion

The analysis of the ΔL_{Ae} computation results obtained by the two methods for the same road situations indicates significant differences in the values, although the character of the changes is similar. The largest differences between the computed ΔL_{Ae} values occur for a distance of up to 250 m for the screen on the reflecting surface ($G = 0$). The ΔL_{Ae} values determined according to ISO 9613 are about 5 dB higher than the ones obtained using NMPB. For $G = 1$ the differences amount to about 3 dB.

Two zones differing in the influence of weather conditions can be distinguished. The boundary between the zones runs at a distance of $250 \ldots 300$ m, regardless of the screen height and the ground surface properties. The weather conditions significantly affect the effectiveness of the screen located on the reflecting surface at a distance less than 250 m (the near zone) and that of the screen on the absorbing surface at a distance greater than 300 m (the far zone).

In the case of NMPB, as the percentage of favourable conditions increases, screen effectiveness decreases. The reduction in the effectiveness of the screening located on the reflecting surface amounts to 4 dB, whereas for distances greater than 500 m it is negligible. In the case of ISO 9613, the influence of weather conditions on the calculated ΔL_{Ae} values is insignificant for the near zone and at greater distances the differences do not exceed 1.5 dB for the extreme values of parameter C_o.

For the absorbing surface of the ground ($G = 0.5 \ldots 1$) the influence of weather conditions is more complex: larger differences in the ΔL_{Ae} values, amounting to $6 \ldots 8$ dB for high screens ($h_e = 10$ m) occur for homogenous and favourable conditions, but favourable propagation conditions do not always cause a reduction in ΔL_{Ae}.

The measurement results show that the time of day at which sound level measurements are performed in order to determine screening effectiveness has a significant influence on the obtained results. The differences between the screen effectiveness determined from measurements made at daytime and at nighttime amount to 1–3.5 dB depending on the location of the observation point. The largest differences occur for observation points located in the central part of the screen where the screening effectiveness is the highest.

The comparative analysis shows that in each of the considered cases the ΔL_{Ae} value obtained from simulations was lower than the one calculated on the basis of the in situ measurements. Almost in each case the differences exceed 3 dB. Agreement between the results was observed for points located near the ends of the investigated screens. The comparison of the computed noise levels with the measured ones indicates that the cause of the differences in the estimates of ΔL_{Ae} are differences in the noise level values determined for the screen situations.

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