Numerical simulation of the sound-emission of truck delivery for supermarkets[3]

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Introduction

In the field of environmental noise protection, the detailed prediction of sound pressure level distributions based on calculations is one of the main topics of interest. The prediction depends on different parameters. Besides the knowledge of the emission parameters, the geometric shape of the situation affects the results significantly. Standard procedure computer models use simple sound sources, an abstract model of the environment and ray tracing to analyse the geometric situation. The pure geometric analysis by ray trace-algorithms just regards the diffraction for free-field propagation in a general way. In complex situations a large number of reflections exist as well. One frequent example with a main relevance is the noise-exposure by delivering processes for supermarkets. This paper discusses the uncertainties of the standard procedure. The quality of prediction is improved by modelling the problem with a wave-based description that is discretized using the Boundary Elements Method.

Motivation

Fig. 1 shows an example of a supermarket project planned in the neighbourhood of residential buildings.

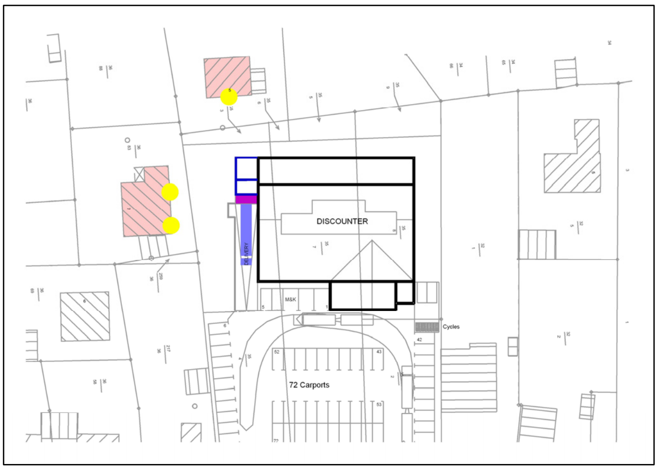

Figure 1: Situation of truck delivery and residential uses

Since supermarkets are often located directly in residential areas the distance between noise emitting sources in the delivery zone and the neighbours is very close. Specific sound emission results from the delivering zone with store and loading ramp. The delivery is done by trucks for usual early in the morning. For an efficient protection of neighbours a realistic prediction of sound exposure is necessary. The protection of neighbours is determined by sound exposure at specific points. These points are the windows of residential rooms. An accurate prediction of sound exposure including sound proofing at these points is what we are interested in.

A prediction of an averaged sound pressure level depends on different parameters:

- sound-power-level of emission
- duration of emission
- and the geometrical shape of the situation

The sound emitting area lies behind the truck where small containers carrying various goods leave the trailer on a mobile metal ramp. The main emission is developed while rolling the containers on the metal ramp. A secondary sound source represents the trailer. This emission is produced by rolling the containers inside the trailer. There are various possibilities for active sound proofing aiming to shield these areas of sound emission. The shielding can be realized by back and lateral walls in combination with additional roofs.

Standard prediction

In fact we have annoying sounds of delivery processes. Sound proofing is necessary to protect the neighbours. A prediction of its efficiency effect is required. The sound field can be predicted using simulation tools based on a wave mechanical approach or a ray model. In practice the standard software uses ray models including sound propagation based on ISO 9613-2[1]. The emission can be represented by a point source in the acoustic centre or a plane source describing the gap between trailer and sound proofing (knowledge of sound power level is necessary). Ray model and ISO 9613-2 lead to uncertainties in predictions as shown in the next section.

To predict the effect of active sound proofing calculations are done using ray tracing based on computer models. The basic concept of screening, diffraction and reflections in the ISO 9613-2 is considered by different terms. Reflections are usually considered by the concept of mirrored sound sources. This concept works for wave-length related to the characteristic dimensions of the screen.

The effects of screening and diffraction are described by a

$$D_Z = 10 \lg \left[3 + (C_2/\lambda)\, C_3\, z K_{met}\right]$$

term D_z:

It represents the difference of sound levels between restricted and unrestricted sound propagation. It depends on the wave-length and two factors C_2 and C_3, K_{met} describing meteorological influences and the variable z. The variable z describes the difference between direct sound propagation and the indirect way around the screen. For vertical diffraction and small distances K_{met} is equal to 1. The presented procedure works for wavelength smaller then typical dimensions of the screen. The red line in Fig. 3 shows for a simple screen and a point source in front of it the reduction of the sound pressure level behind the screen at discrete points calculated using a ray model and the ISO 9613-2 propagation. The left part of the red curve shows sound pressure levels at points with no optical connection (z is larger than zero). When source and receiver get optical connected z and D_z is zero and a discontinuity results (right part of the red curve).

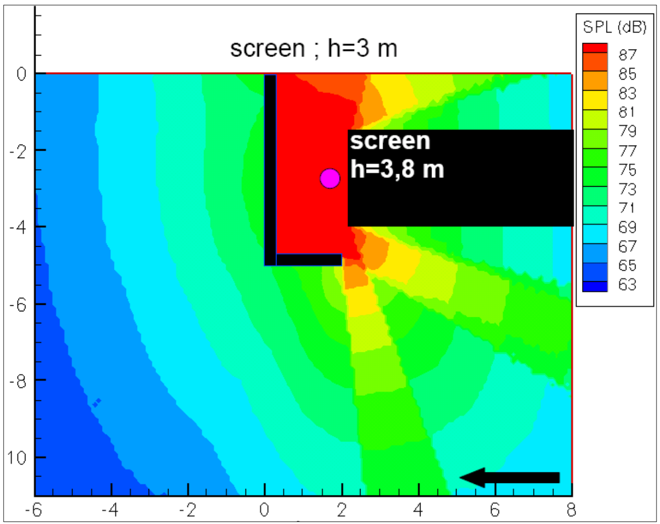

Figure 2: Ray-trace based propagation

Fig. 2 shows a contour plot of a more complex application. A screen and a box which represents the trailer are considered. The calculation uses a ray model including ISO 9613-2 propagation. An arbitrary sound power level of 100 dB(A) of the source is assumed. The red areas show sound pressure levels above 87 dB(A). The calculations are done including reflections. One can see “jets” due to direct sound propagation and a first reflection. The contour plot shows an inaccuracy up to 5 dB(A) on a distance of a few centimetres at these discontinuities.

Wave mechanical approach

The basic idea of improving the prediction of sound level distributions is the use of the numerical methods of a wave mechanical approach. The well known Helmholtz equation can be transformed in an integral formulation with respect to the boundary by using the method of weighted residua using the fundamental solution as weighting function. Discretizing the boundary and the use of the method of collocation leads to an algebraic equation system which can be solved numerical (BEM).

Fig. 3 compares the sound field behind a single screen calculated with ray model and BEM. The wave based calculation describes a more realistic sound field (blue line). The discontinuity vanishes. Hence the expected improvement in absolute sound pressure level is about 4 to 5 dB(A). It is obvious that the wave mechanical approach leads to sound pressure levels below the standard prediction. In a wave mechanical description the effect of the screen is still relevant in the direct surrounding of it.

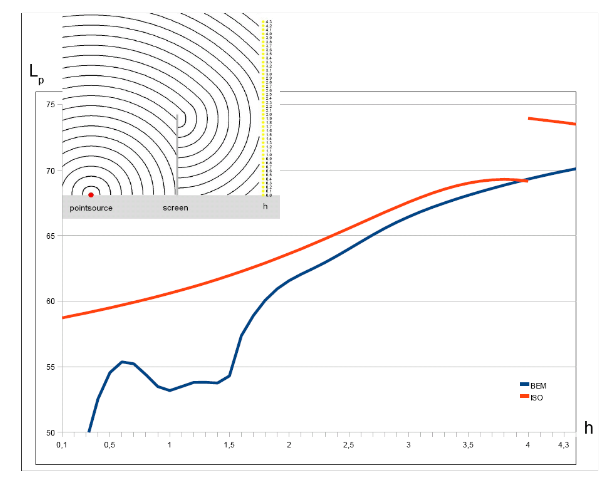

Figure 3: Improvement of wave mechanical approach

Fig. 4 shows results of this wave mechanical approach for a more complex situation. The boundary conditions are of Neumann type. This means the sound flux on the surfaces is zero. It is obvious that these calculations give a more realistic prediction of the effect of active sound proofing.

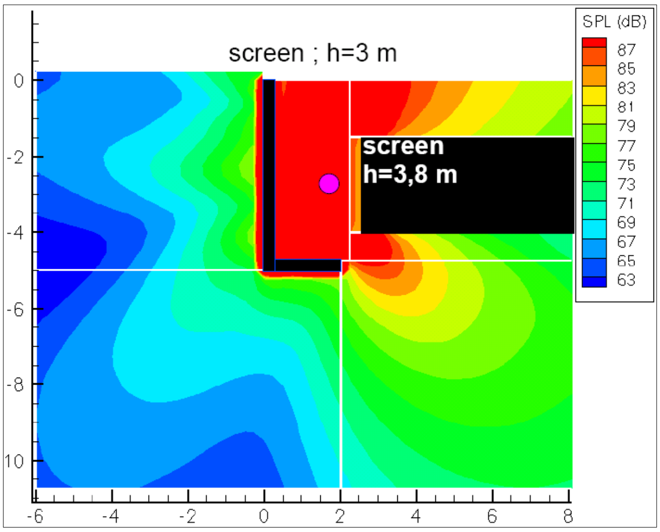

Figure 4: Wave mechanical approach

In the future this approach will be applied to representative situations of sound proofing at delivery zones. This creates a database of sound distributions from different topologies of sound proofing. No further BEM studies are necessary except for totally different situations. Bypassing the complex geometry with BEM calculations the resulting sound field will be reconstructed by a number of point sources. This serves an alternative source model for a more physical description of these sound fields. This source model can be used in standard prediction software for calculations with reliable unrestricted sound propagation.

References

[1] DIN ISO 9613-2, Dämpfung des Schalls bei der Ausbreitung im Freien, Teil 2: Allgemeines Berechnungsverfahren (Oktober 1999)