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A HYBRID CALCULATION TOOL FOR THE EVALUATION OF COMPLEX NOISE BARRIER GEOMETRIES INCLUDING METEOROLOGICAL EFFECTS

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ABSTRACT
The Dutch standard calculation method (SRM) is the only statutory calculation model for the acoustical evaluation of roadside noise barriers in the Netherlands. This method however, is limited with respect to barrier complexity and propagation distance. To overcome this problem, the Dutch Ministry of Transport Public Works and Water Management asked TNO to design correction terms for tilted barrier configurations. A two-stage hybrid modelling approach was chosen in which two advanced calculation models, TOMAS and PE, were applied to maximise their combined capabilities. The effect on the propagation through a disturbed sound velocity field, due to the presence of the barrier, was taken into account. The hybrid model has been applied to study single and double, vertical and tilting, reflective and absorbing noise barrier configurations for elevated and depressed roads and roads at ground level.

1 - THE EFFICIENCY OF NOISE BARRIERS ON BOTH SIDES OF A ROAD
The Dutch Ministry of Transport Public Works and Water Management gets an increasing number of questions on parallel noise barriers and the effect of these barriers on noise immission levels. It is known that vertical reflective parallel barriers lead to a decrease in barrier efficiency, compared to the efficiency of a single side barrier, due to reflections against the barrier at the opposite side of the road. A solution to this problem is the use of absorbing barriers or of tilted reflective barriers. The use of the absorbing type is avoided, due to maintenance and cost aspects.
Since the number of situations with barriers on both sides of the road is increasing, there is a need to study the acoustical effect on the immission of double tilted barrier configurations. To put the question more specifically: is it possible to avoid the reflection influence by using this type of barrier configuration and will the obtained effect holds for greater distances from the road?

2 - NOISE PROPAGATION MODELS
The Dutch standard calculation model provides two versions for the prediction of noise immission levels [1]. SRM-I is a simple one, that does not include the effect of noise barriers and only operates in dB(A). SRM-II is more detailed, includes barrier effects based on the Maekawa theory and operates in octave bands. SRM-II has been designed some twenty years ago and was not equipped to predict the effects of tilted barriers and complex double-sided barrier configurations. Also the field of application is restricted to distances up to 600 m. In case of doubt and in cases outside the validity range of the SRM model, a more detailed study is required. TNO has performed many of such studies relying on the use of advanced in-house developed calculation models such as TOMAS and PE. These calculation models have been improved over time through a continuous process of updating and validating based on the application of newly developed theoretical insights, measurements and comparison with data from literature. TOMAS [2,3] is regularly applied in detailed analyses of barrier effects. It is a semi-empirical model, based on noise propagation by straight rays and on theoretical formulas for diffraction

and reflection. TOMAS takes the phase relation of rays originating from the same source into account. In the Euroecran project, a Brite-Euram project for designing an optimal cost-effective barrier for high-speed railway lines, TOMAS has been compared extensively with a boundary element method (BEM) in 2-D and in 3-D, the latter by the use of Duhamel's method [4]. TOMAS is well equipped to include effects of multiple reflections and diffractions in cases of complex barrier geometries but is only valid in a homogeneous atmosphere. The use of TOMAS is therefore limited to short distances from the source. Specifically for greater distances a second calculation model is applied: PE (Parabolic Equation). This is a one-way noise propagation model based on a finite difference scheme first presented in outdoor acoustics by Gilbert & White [5]. A non-homogeneous atmosphere can now be defined in terms of windspeed and temperature profiles. Together these define the sound speed, and more specifically the gradients of the sound speed along a sound path as a function of distance and height. When these gradients are positive, the noise is refracted towards the ground, which causes higher noise levels. When the sound speed gradients are negative, noise is refracted away from the ground; this causes a noise shadow. Turbulence can also be incorporated in the PE calculations. PE is well suited for the analysis of propagation effects over large distances and provides output on a grid of observer positions.

3 - THE HYBRID APPROACH

To study the complex barrier configurations for observation points far behind the barrier, the models TOMAS and PE are used in combination. TOMAS takes into account all aspects in the direct vicinity of the road, assuming locally a homogeneous atmosphere. TOMAS calculates columns of complex pressures just behind the noise barrier. These are subsequently used as input for PE. With this model, the propagation in an inhomogeneous atmosphere towards greater distances from the road is calculated. This procedure is repeated for a number of observation angles from the receiver point towards the road. The calculations with the hybrid TOMAS/PE model result in a frequency dependent excess attenuation. This attenuation is then combined with the distance attenuation and corrected for air absorption per sector. Next octave band results are derived and weighted with the source spectrum as recently suggested for the update of the Dutch standard calculation model.

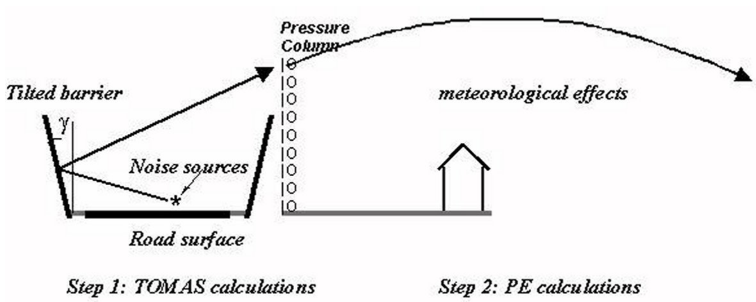

Figure 1: The hybrid method TOMAS-PE: a two-stage modelling approach.

The hybrid approach is computer intensive, therefore some simplifications were made: (1) reducing the number of incoherent line sources representing driving lines, (2) reducing the number of observation angles, (3) a quasi-3D approach to parallel barriers, (4) a reduction in the number of spectral components to be calculated and (5) a limitation of the number of reflections to the first order reflections.

The combined result of the calculations is a L_{Aeq} estimate for a dense grid of observation positions as function of distance (up to 2 km) and height (up to 50 m). The data are represented in nomograms with iso- dB(A) contours. Figure 2 shows the results up to 600 meters for a single and double vertical reflective barrier configuration.

The difference between these L_{Aeq} values results in correction terms that are to be used in addition to reference calculations made by the Dutch standard calculation model for the single barrier reference. Such correction terms were prepared for a number of barrier configurations.

4 - CONFIGURATIONS THAT HAVE BEEN STUDIED

Calculations were made for single and double sided barriers, reflective and absorptive, in vertical and tilted positions at an angle of + and − 10 and 20 degrees with the vertical in different configurations such as:

- Roads at ground level with noise barriers of 3 and 6 meters

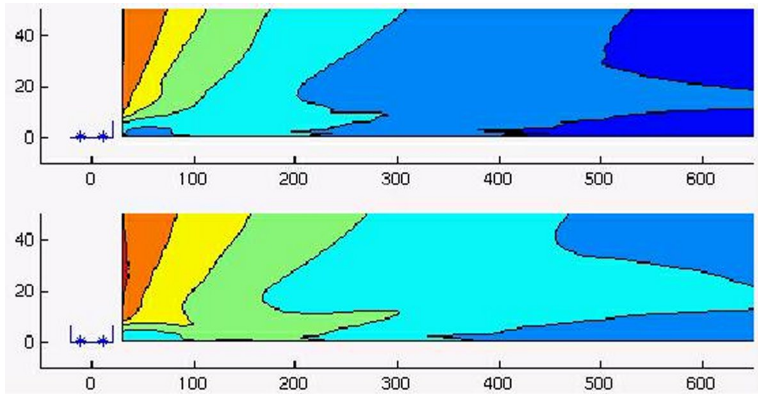

Figure 2: Modelled L_{Aeq} for a single and double, 6 meter high barrier configuration as a function of distance and height (iso-contouring every 5 dB(A)).

- Elevated roads at 3 meters above ground level, with noise barriers of 3 meters
- Depressed roads at 4 meters below ground level with an additional 1 meter barrier.

Specific questions were:

- Is it possible to avoid the negative effect of a single vertical reflective barrier on the noise levels on the opposite side of the road by using a tilted barrier? What is the difference of this effect compared to an absorptive vertical barrier?
- Is it possible to avoid the negative effect of a second vertical reflective barrier on the opposite side of the road on the noise levels in the neighbourhood, by tilting the second barrier? What is the difference of this effect compared to an absorptive second vertical barrier?

5 - GENERAL RESULTS

In figure 3 a bar chart is shown as a result of the study on double barrier configurations. The zero dB(A) axis here represents the reference case of a single barrier. Vertical reflective barriers clearly reduce the barrier effect. Situations with an angle of 10 ^{0} towards the road prove to be less sufficient in avoiding this negative effect. Situations with an angle of 20^0 towards the road or angles of 10^0 or even 20^0 outwards prove to be equivalent or in the latter case even better than absorbing barriers. The effects are valid for distances up to 2 km from the road.

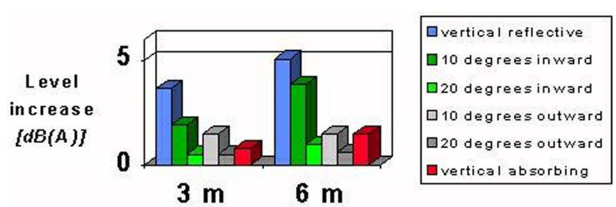

Figure 3: Averaged L_{Aeq} level increase in dB(A) due to the placing of an additional second barrier at the opposite side of the road relative to a single barrier of equal height.

6 - CONCLUSIONS

By combining two advanced noise propagation models, a hybrid model has been created, that is capable of predicting barrier effects for complex barrier configurations. This model has been applied to a number of single and double complex barrier configurations. The main conclusion of the study is that by using tilted reflective barriers, placed either at one side or at both sides of the road, the effects of unwanted reflections can be sufficiently reduced. The minimum tilt angle of the barriers should be at least 10^0 outwards.

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