



Enhancing the Dutch engineering calculation method

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ABSTRACT

With the advent of new legislation, we have taken the opportunity to take a serious look at the Dutch national calculation method. This method, which is similar to ISO9613-2, needed enhancements to allow for the increasingly complex world outside. Objects like leaning barriers or diffracting elements on barriers are seen more and more. The 3D datasets that are available for noise models are much more complex compared to the time, many years ago, when these calculation methods were conceived.

To allow for these situations we have made several improvements to our method. Reflections can now occur in 3D. This allows for leaning barriers. We take the size of objects into account to determine the fraction of noise reflected. Based on the Cnossos method, a direction dependent meteorological correction is now used. Methods to account for diffracting elements in the ground and on barriers have been developed. Many of these enhancements could be used in other methods like CNOSSOS-EU or other engineering calculation methods. In this paper we present the main changes to our method.

1. INTRODUCTION

With the advent of new legislation, we have taken the opportunity to take a serious look at the Dutch national calculation method RMG. Because the way we assess noise is going to change, the impact of changing our method is relatively small even though the results produced will be different. This paper presents several enhancements for calculating road and railway noise that we introduced. The changes were prompted by research into CNOSSOS-EU, by new developments of noise measures or by the availability of better or more detailed datasets used in noise models.

2. METEOROLOGICAL CORRECTION

In CNOSSOS-EU calculations are performed for homogeneous and favourable conditions, where in ISO9613-2:1996 and the Dutch RMG (SRMII)[1] methods only favourable conditions are considered. These two methods use a general meteorological correction based on the distance between source and receiver (d_p) and source/receiver heights (h_s and h_r). The formula used is shown in Equation 1:

$$C_m = C_0 [1 - 10(h_s + h_r)/d_p] \quad (1)$$

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In the Netherlands the value C_0 is set to 3.5 dB.

There is no dependency on the propagation direction in this formula even though in the Netherlands the prevailing winds are from the south-west. An often heard complaint by the general public is that the calculated noise level is not representative because they live to the north-west of a source. Therefore their situation is much worse than the calculation suggests.

When CNOSSOS-EU was implemented in our legislation a research project was carried out by TNO [2] to determine the percentage of favourable conditions in steps of 20 degrees in direction. It was found [3] that a function could be fitted so that smooth transitions between propagation directions are achieved. In Figure 1 we show the fit and the fraction of favourable conditions as a function of propagation direction.

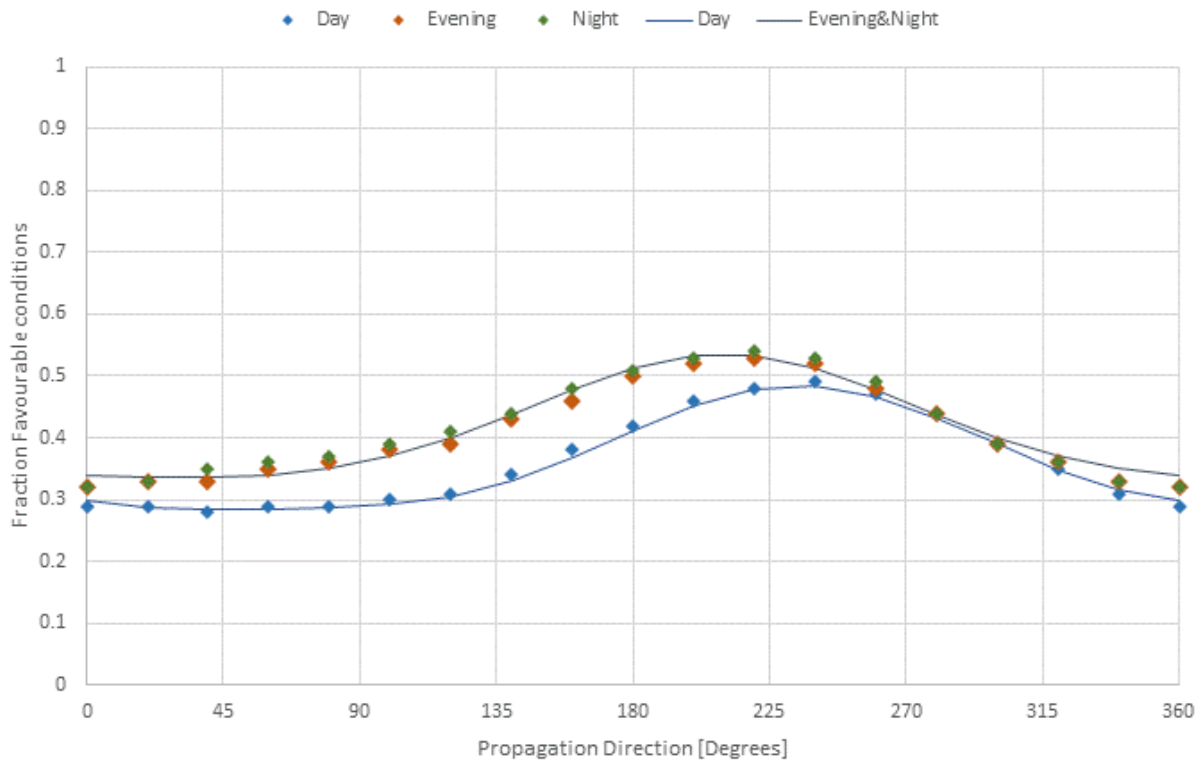


Figure 1. Fraction of favourable conditions as function of propagation direction where 0 degrees indicates northbound.

A single fit was used for evening and night because the fractions are almost the same. Based on these fits the constant of C_0 in Formula 1 was made equal to C_d for the day period and equal to C_{en} for the evening and night period. C_d and C_{en} are calculated according to formulas 2 and 3.

$$C_d = -10 \cdot \lg(0.34 - 0.1 \cdot \sin(\zeta + 35) + 0.045 \cdot \sin^2(\zeta + 35)) - 0.67 \quad (2)$$

$$C_{en} = -10 \cdot \lg(0.40 - 0.1 \cdot \sin(\zeta + 60) + 0.035 \cdot \sin^2(\zeta + 60)) - 0.67 \quad (3)$$

The value 0.67 was introduced to make sure the average meteorological correction is equal to the same value of 3.5 that was used before.

In figure 2 an example of the consequence of this change is shown for a simple line source:

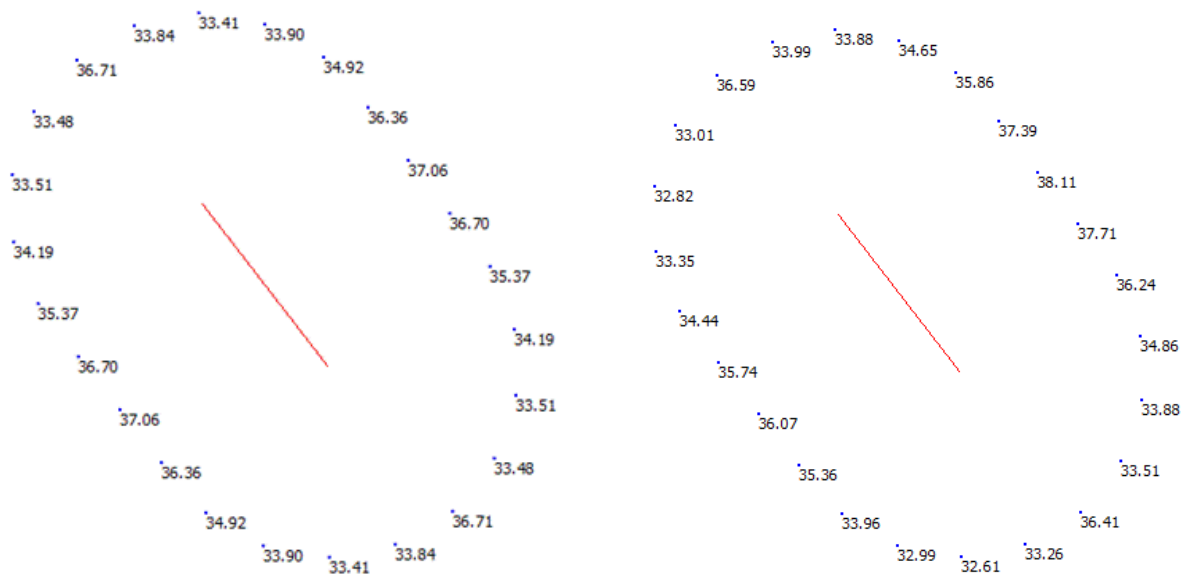


Figure 2. Noise levels with direction independent meteorological correction (left) and the new method (right).

As is shown in Figure 2, a difference of up to 2 dB can occur depending if one looks to the northeast side of the line source or to the southwest. This change made to our method adjusts the results to align more with real-world situations and will help in the acceptance of results of noise models by the general population.

3. REFLECTIONS

Datasets are getting more and more detailed. While a building would be modelled in the past by drawing a simple rectangle, nowadays datasets that contain much more detail are imported instead. An example of buildings with more detailed facades is shown in figure 3

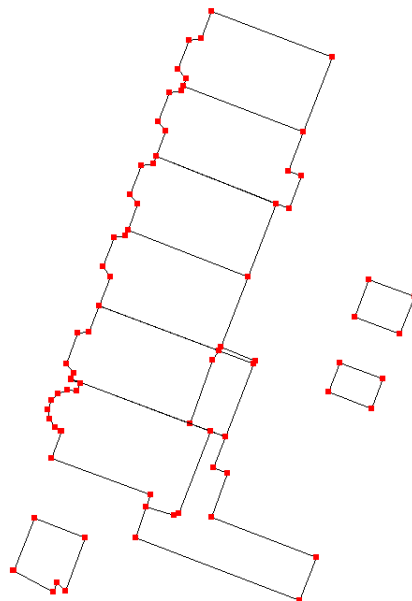


Figure 3. More detailed building footprints (e.g. including bay windows and extensions) as incorporated in the Dutch National Building database [4].

In the old description of the calculation method it was not clear to software developers how to handle these type of building situations with respect to reflections. One approach is to have a reflection in an object just by looking at the propagation paths that crosses objects. Size of an object is no consideration in this approach. This approach is not according of RMG or ISO 9613, because there objects only reflect if a size criterion is fulfilled. The other approach is to consider each segment between two nodes as a separate object and then assess if this object is large enough. In this approach adding more nodes leads to fewer reflections. With many nodes, reflections can even be eliminated altogether. We now have clarified this in the RMG. A reflection will occur if the segment or combination of segments (this can also originate from different objects) is wide enough. In that case the reflection path is determined by the original segment that crosses the propagation path. In figure 4 the difference of using segments (the second approach) or combining segments (the new approach) is shown for the building set from figure 3. Both direct and reflected paths are shown.

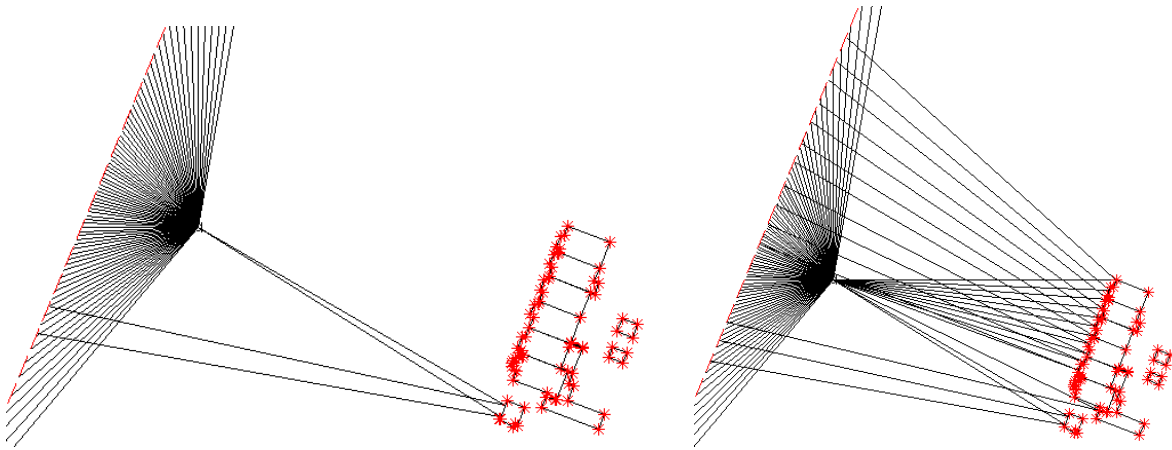


Figure 4. Propagation paths with reflections by assessing segments (left) and reflections by combining segments to assess size (right).

In figure 4 it is clear there is a large difference between these two approaches. And although the new approach could have been used before, this clarification assures that different software applications give the same results.

A second change is very new to our method. This is to use the vertical size of an object to calculate a fraction of the noise that is reflected. The method is similar to what is used in NORD2000 [5] where the overlap of the Fresnel zone with the barrier is used. What also changed is that the reflections are now calculated in three dimensions. That allows for the modeling of leaning barriers. In principle the overlap is calculated by equation 4

$$\Delta L_F = 20 \lg(S_r/S_F) \quad (4)$$

The use of this formula was slightly modified based on research by TNO [6] where a comparison of the method with BEM-PE (Boundary element method and parabolic equation) calculations was made. The modification is that the value ΔL_F is first calculated for the 63 Hz octave band. For each successive octave band the increase in the value for ΔL_F is maximized to 3 dB.

The change to make reflections in 3D has as consequence that many more geometries can be assessed. An example for three geometries is shown in figure 5.

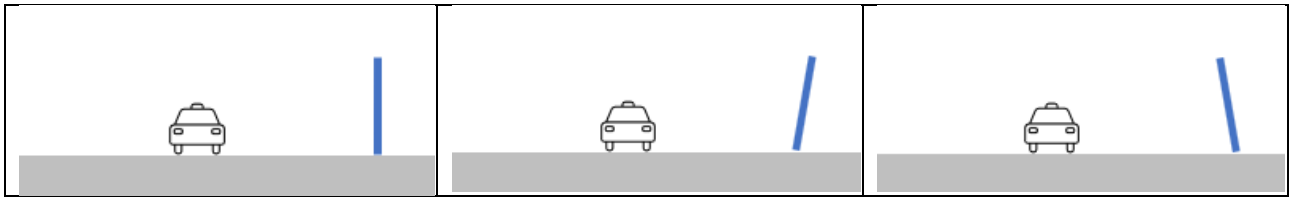


Figure 5. Three examples of barriers.

Some examples of calculations with the barrier configurations shown in figure 5 are presented in figure 6. Presented is the added contribution to noise levels due to reflections. The barriers in the model were 5 meters high and 15 meters from a line source.

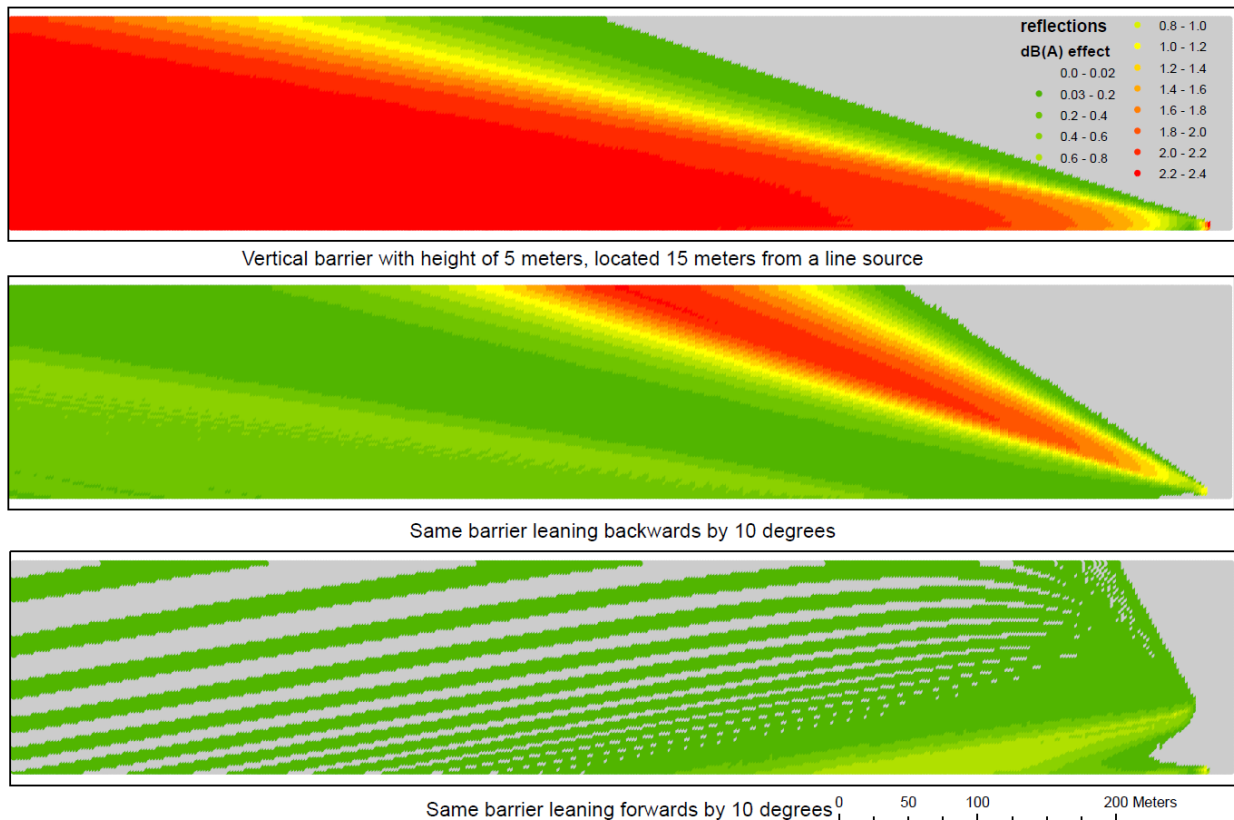


Figure 6. Contribution of reflections on noise levels for three different barrier configurations.

In the example shown in figure 6 it is clear that reflection in a leaning barrier has a much smaller contribution on noise levels compared to a straight barrier. However, a similar calculation can be performed when a second barrier to the other side of the source is included. For this example, the second barrier is modelled as fully absorbing. The three models are shown in figure 7.

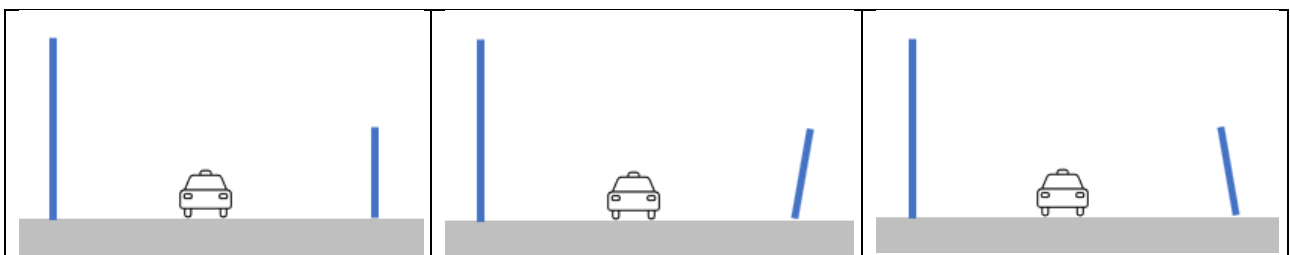


Figure 7. Three examples with two barriers.

The results of these configurations are shown in figure 8.

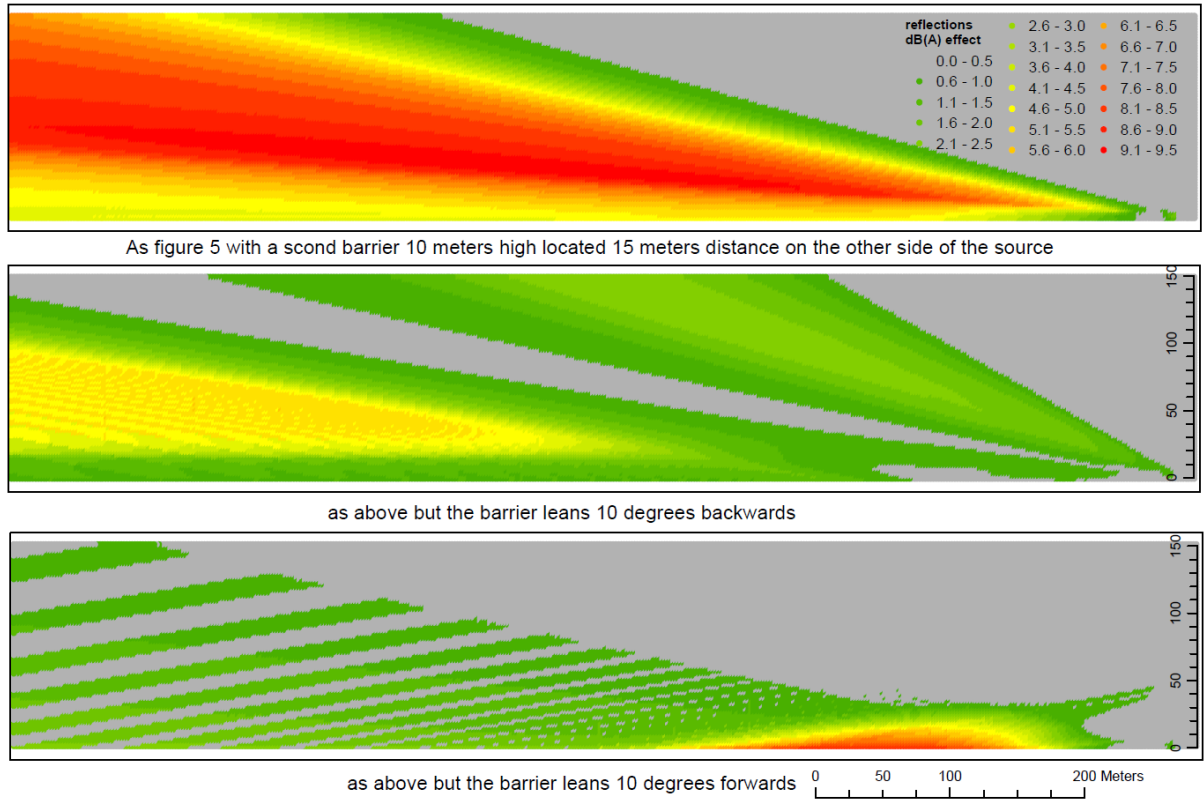


Figure 8. Contribution of reflections on noise levels for three different barrier configurations with two barriers

In figure 8 we show that including a second barrier leads to a very different result. When a barrier is used that leans forwards the screening effect of the second barrier is reduced. This can lead to a contribution of the reflections to noise levels of up to 9 dB. With this enhancement of the method competent authorities can optimize design of barriers.

4. DIFFRACTING ELEMENT ON BARRIER

A recent innovation is the application of specifically tuned diffracting elements on noise barriers. The so-called WHIS®wall[7] or WHIS®top[7] are now included in a simple way in the RMG method. The effect of a diffracting element on noise attenuation by a barrier is included as a simple (frequency dependent) added effect. The basic formula used is shown in equation 5.

$$\Delta L_{SWN} = HF(N_f) + C_{s,diff} + C_T - C_P \quad (5)$$

with ΔL_{SWN} as the attenuation due to an object. The correction term $C_{s,diff}$ has been included in the case of a barrier. The correction terms C_T and C_P are pre-existing terms for a T-top on a barrier (C_T) or for an embankment (C_P). These two terms are equal to 0 dB in the case of a diffracting element on a noise barrier.

To achieve a new calculation scheme, measurements [8] and numerical calculations [9] were performed. The end result is a measurement method to determine the characteristics of a diffracting element and a simple calculation schema (that makes use of the measured characteristics) for determining the effect of this element in noise models.

The measurement method used to determine the characteristics is the same as the European standard 1793-4 with the exception that the diffraction index is not calculated by averaging the measurement positions energetically but by averaging arithmetically. The result of these measured characteristics are terms $A_{i,S,diff}$, where i is the octave band number. The value $C_{s,diff}$ is then calculated as follows

$$C_{s,diff} = \begin{cases} 0,20 A_{i,S,diff} D_{schem}(N_f) & \text{when } A_{i,S,diff} < 0 \\ 0,05 A_{i,S,diff} D_{schem}(N_f) & \text{when } A_{i,S,diff} \geq 0 \end{cases} \quad (6)$$

with

$$D_{schem}(N_f) = 10 \lg[\max(1; 20N_f + 3)] \quad (7)$$

where N_f is the Fresnelnumber. This value N_f is already calculated to determine the normal attenuation for a barrier. However, in the RMG a source height for road noise of 75 cm is assumed. In the simulations [9] a source height of 10 cm was used. Because of this, it is necessary to decrease the source height by 65 cm before determining the Fresnelnumber. However even with this decrease we noticed a slight underestimation of the calculated effect compare to measurements at short distances behind a barrier with diffractor. This was solved by keeping the source height at 75 cm and adding 65 cm to the barrier height when calculating the Fresnelnumber. This is effectively the same as decreasing both source and receiver height by 65 cm. We note that this is only done in the calculation of the extra effect of the diffractor. There is no change when calculating the normal barrier attenuation. No heights are adjusted for rail traffic noise calculations.

We have compared the effect of the calculation method with measurements. These measurement [8,9] were performed behind a barrier and a barrier including the diffracting element (WHISSwall). This is shown in figure 9.



Figure 9: WHISSwall and adjacent a barrier with equal height at the measurement location [9]

Figure 10 shows the measurement positions.

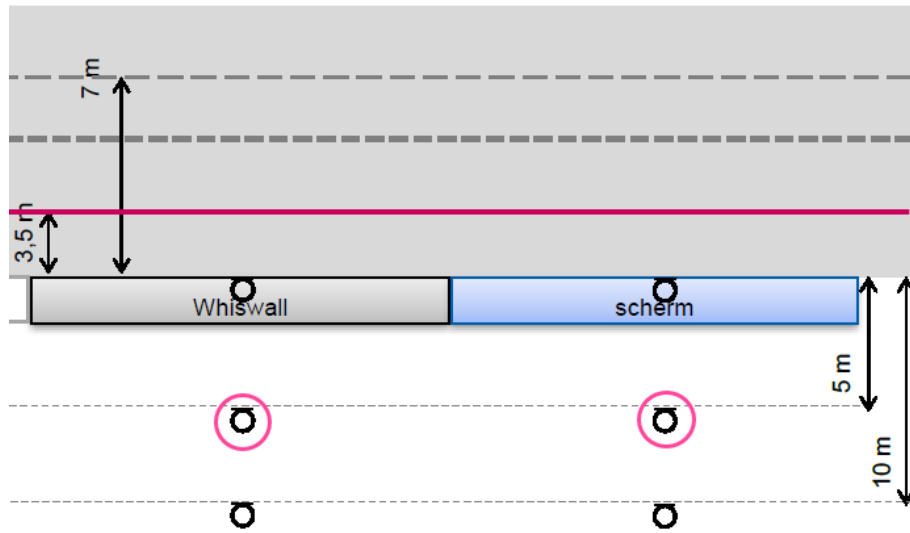


Figure 10: Measurement positions. In this article the results for the source (vehicles driving by) at 3.5 meters (red line) and for receivers 5 meter behind the WHISwall/barrier is presented.

The values for $A_{i,s,diff}$ needed in the method were obtained by separate measurements with a 4-meter-high barrier with the same diffracting element on top.

In figure 11 the measured difference between barrier and WHISwall is compared the calculated results with the new RMG. This is shown for microphone positions 5 meter form the WHISwall at a height of 1.2, 2.0 and 3.0 meters and for the source at 3.5 from the WHISwall.

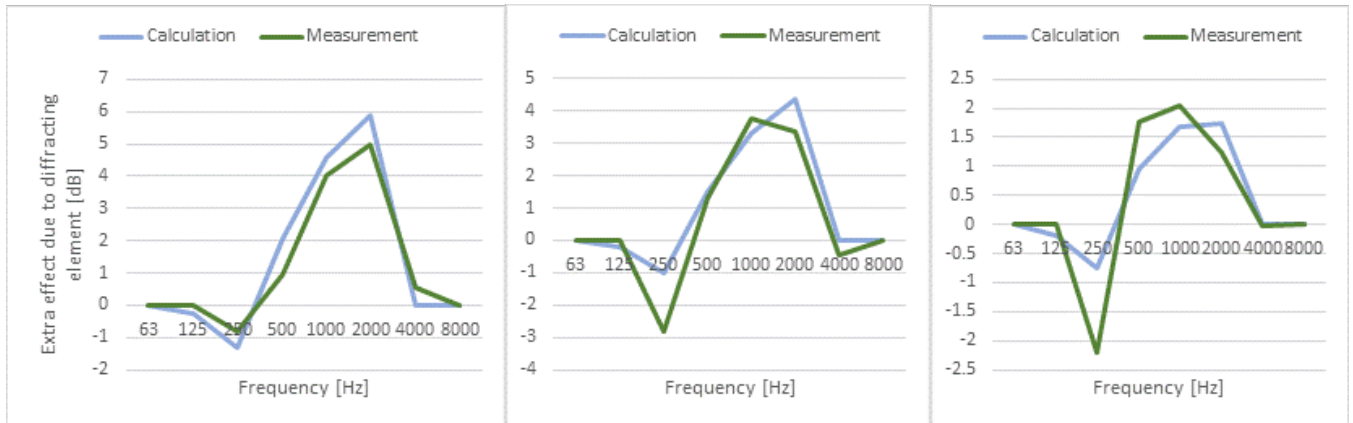


Figure 11: Measured and calculated effect of the diffracting element for heights of 1.2, 2.0 and 3.0 meters (left, middle and right)

The overall levels are shown in figure 12.

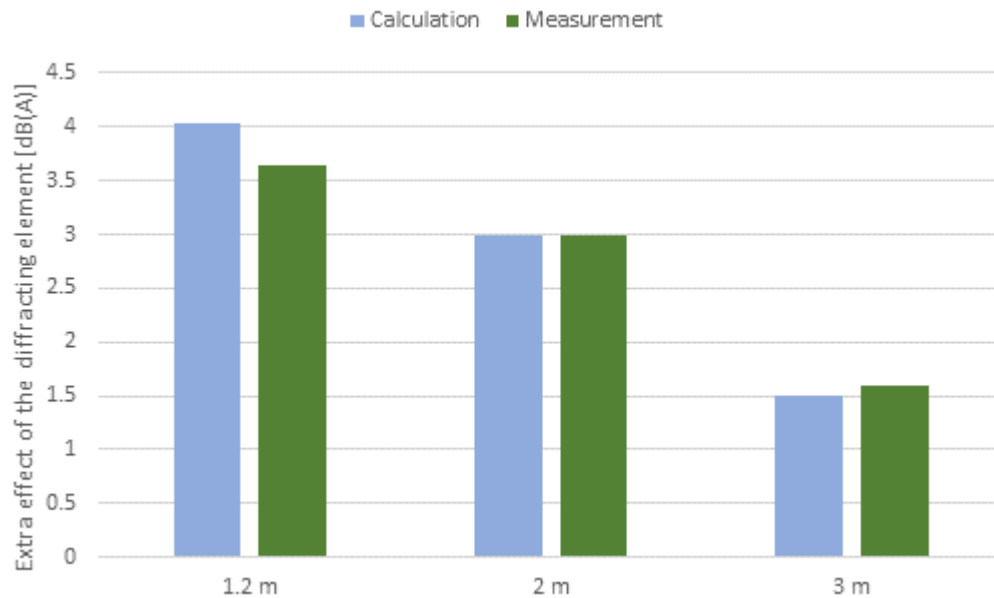


Figure 12: Measured and calculated effect of the diffracting element

As shown, there is a good agreement between measurements and the results obtained by calculations using the method described.

With this change we now have a method to include diffracting elements on noise barriers. Because measured characteristics of a product are used in this method it is also applicable to other types of diffractor that uses the same basic principles. For validation we compared FEM-PE calculations to the simple calculation scheme to a differently tuned diffractor and got comparable results.

5. FURTHER CHANGES

Apart from these changes we will also have made some minor other changes. We will use newly determined emission values for motor vehicles and we have changed the way we incorporate acoustical aging of road surfaces when measurements on new surfaces are performed.

For the emission of motor vehicles, the exact values are still being determined. From preliminary measurement results we notice that, compared to 10-15 years ago, emissions at low speeds are lower, but at speeds above 80 km/h they are higher. The consequence is that for low-speed roads in cities we expect 3-4 dB lower noise levels and at highways we expect 1-2 dB higher noise levels.

For determining the acoustical characteristics of road surfaces often measurements are performed. These measurements are mainly performed on newly laid surfaces. As we want to know the average noise reduction during the lifetime of a road surface a generalized aging term is often used. This aging term gives an amount of dB that should be added to the measured noise reduction of a new road surface. This value differs for different road surface types, but is the same for different product of the same type (e.g. thin surface layer).. When there is a product with a surface type that has a very high noise reduction the same aging term was used compared to a product with a lower noise reduction. We expect however that at the end of life of these surfaces both will be equally quiet (or noisy). So instead of using a fixed aging value we use a fixed end of life value and interpolate between initial and end of life value to obtain the average surface characteristics. The result is that surfaces that initially perform very well do not have that same high bonus when being used in calculations and follow the general aging process as surfaces in the same category.

6. CONCLUSIONS

Thanks to the opportunity given by a change in legislation we have made numerous changes to the Dutch National method for road traffic and railway noise. With these changes we achieve more accurate results and can handle more complex situations within noise models.

7. REFERENCES

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