Acoustic effect of absorbing embankments as noise barriers

Sebastian Köper[1], Sebastian Eggers[1], Folkard Hänisch[1]

Andreas Fuchs[2], Manfred Haider[2]

[1] *Lärmkontor GmbH, 22767 Hamburg, E-Mail:s.koeper@laermkontor.de*

[2] *AIT Austrian Institute Of Technology, 1210 Wien, E-Mail:andreas.fuchs@ait.ac.at*

Introduction

The guideline for noise protection on roads (RLS-19) takes the reduction effect through shielding into account in a simplified manner when calculating sound propagation. The sound path over up to two diffraction edges and a weather correction are considered. Other influences such as the surface of the obstacle or the nature of the ground in front of or behind the obstacle are not taken into account.

In the case of embankments, measurements in the past have shown level differences of up to 8 dB compared to calculations according to RLS-19 [1]. On behalf of the Federal Highway Research Institute (BASt), LÄRMKONTOR GmbH and the Austrian Institute of Technology AIT investigated the effect of absorbing embankments and photovoltaics on embankments in the research project "Acoustic effect of embankments as absorbing noise barriers". The aim was to investigate the effect of the sound-absorbing properties of vegetation and the influence of photovoltaics on sound propagation behind embankments. A comparison with RLS-19 and another current calculation regulation for traffic noise was also intended to assess the possible need for action in the consideration of embankments in RLS-19.

For this purpose, measurements were carried out on two embankments on federal highways in Germany and compared with calculations according to RLS-19 [2] and the Scandinavian calculation rule Nord2000 [3].

Measurements

The measurements were carried out in accordance with ISO 10874 [4] on two embankments on the A92 freeway near Hettenkofen and the A94 freeway near Töging. ISO 10874 provides for measurements on the cross-section of the embankment as well as on a reference cross-section in order to determine the insertion loss through the barrier. The reference cross-section must be as consistent as possible with regard to "the source, the terrain profiles, [...] ground surface and meteorological conditions" [4]. The location of the respective cross-sections is shown in Figure 1.

In Töging, there are photovoltaic systems (PV) on part of the embankment on the side facing the road. Accordingly, two cross-sections of the embankment (without PV and with PV) were examined here.

The measurement was carried out at 9 measurement positions. The four reference positions are located at a distance of 7.5 m from the center line of the next lane at a height of 1.2 m and 3 m high (*Street low* and *Street high*) and on the top of the embankment at 1.5 m and 3 m (*Berm low* and *Berm high*). The receiver positions are located at the base point behind the embankment 2 m below the top of the embankment and at a distance of 5 m and 20 m from the base point at a height of 1.5 m and 5 m (*5 m low*, *5 m high*, *20 m low* and *20 m high*).

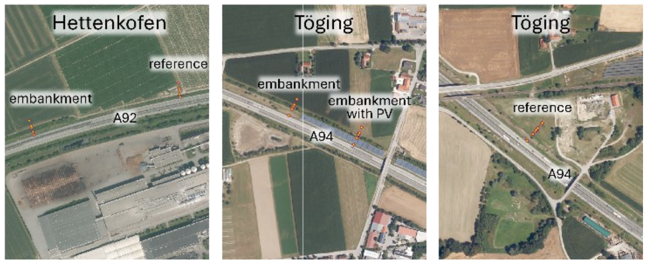

Figure 1: Top view of the terrain around the measurement cross-sections on the BAB 92 in Hettenkofen and BAB 94 in Töging with the individual measurement positions

Source: Bayerische Vermessungsverwaltung – www.geodaten.bayern.de

Figure 2 shows the terrain cross-sections in Hettenkofen and Töging for the cross-sections at the embankment (black) and the reference cross-sections (gray) together with the measurement positions (blue: measurement at the embankment, light blue: measurement reference cross-section). The location of the highway is marked in red, the location of the PV system and a wall on the embankment in Töging in blue and green.

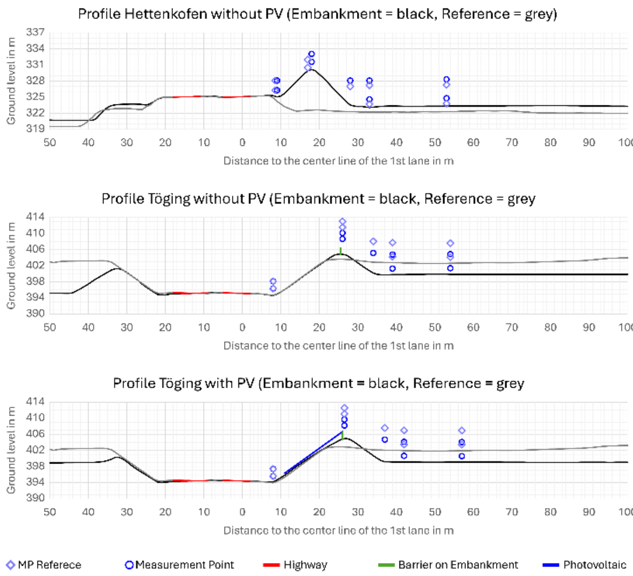

Figure 2: Terrain cross-sections in Hettenkofen and Töging at the reference cross-sections (gray) and the embankment (black) without and with PV with the respective measurement positions (blue: barrier; light blue: reference)

Source: own graphic

The meteorological conditions (temperature ϑ_L, air pressure p_L, relative humidity RH_L, wind direction and wind speed v_W) during the measurements at the different cross-sections are summarized in Table 1.

The traffic on the highways was recorded during the measurements and taken into account accordingly in the calculations.

Table 1: Meteorological conditions during the measurements in Töging and Hettenkofen

Profile	ϑ_L in °C	p_L in hPa	RH_L in %	Wind-direct.	v_W in m/s
Töging (PV)	30	967	43	E	1,0
Töging (PV, ref.)	22	978	63	SE	0,3
Töging (grass)	26	970	60	W	1,0
Töging (grass, ref.)	21	978	69	SE	0,4
Hettenkofen (grass)	27	977	37	WNW	0,7
Hettenkofen (grass, ref.)	28	976	43	S	0,9

Calculations

The calculations were carried out using the SoundPlan Noise 9.0 program in a three-dimensional sound propagation model. The model contains the terrain according to a digital terrain model with a grid width of 1 m (DGM1), the surrounding buildings, the course of the highway, the measurement points in position and height as well as ground effect areas in the vicinity of the measurement cross-sections. The embankments are already included in DGM1 and do not need to be modeled additionally. Only the 1.5 m high wall on the embankment in Töging was included as an additional object in the sound propagation model.

Calculation of the insertion loss according to ISO 10847

The insertion loss according to ISO 10847 can be determined from measurements using a direct and an indirect method. For an existing wall, only the indirect method, which requires a reference cross-section, can be used. A reference point ($L_{ref,A}$) and a receiver point ($L_{r,A}$) are measured on the cross-section of the embankment and a reference point ($L_{ref,B}$) and a receiver point ($L_{r,B}$) are measured on the reference cross-section. The reference points and receiver points must be as identical as possible in their position. According to equation 1, the insertion loss then results from a double level difference.

$$D_{\mathrm{IL}} = \left(L_{\mathrm{ref,A}} - L_{\mathrm{ref,B}}\right) - \left(L_{\mathrm{r,A}} - L_{\mathrm{r,B}}\right) \quad \text{in dB} \quad (1)$$

Modelling of traffic noise

Emission levels from road traffic are determined in the two directives under consideration using similar input variables. Among other things, the speed of the vehicles, road conditions and hourly traffic volumes are taken into account. When modelling the lanes, different approaches were taken for the guidelines. While RLS-19 only provides for one emission band per direction of travel, each lane was modelled with its own emission band for the calculations according to Nord2000.

The sound propagation of traffic noise is calculated in RLS-19 based on ISO 9613-2 [5]. The methods developed for Nord2000, on the other hand, are based on different theoretical and empirical models and are explained in more detail in the relevant literature [3] [6] [7].

The calculation and output of the rating level for the RLS-19 is only carried out as a sum level. In the Nord2000, on the other hand, both the emissions and the calculation results are presented spectrally as one-third octave levels.

Leveling the calculation results

Since, as described, the emissions from traffic in the calculation rules are calculated in different ways, the results must be leveled to a common reference point for the subsequent comparison of measurement and calculation. The reference position *Street high* was chosen for this purpose, as the influence of reflections from the wall and PV is comparatively low here and any deviating ground effects in the Nord2000 are less significant at low heights.

For the calculated insertion losses, it can be expected that leveling will not affect the values. As these are level differences, the level corrections of the leveled values cancel each other out. Figure 3 shows, however, that there are slight deviations between the insertion loss of unchanged and leveled values for the Nord2000. The graphs show the insertion loss from the Nord2000 calculation (unadjusted and adjusted results) at the embankment in Hettenkofen at the five receiver positions for each of the four reference positions. The differences are due to the fact that the Nord2000 results were leveled in the one-third octave spectra.

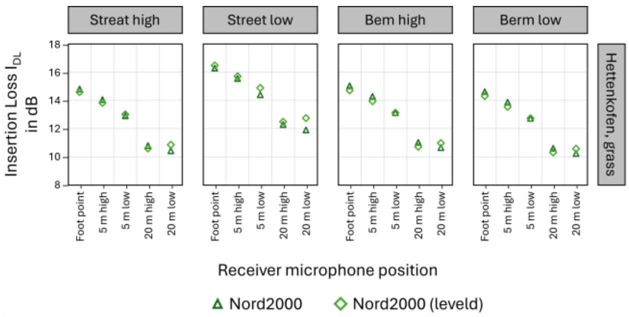

Figure 3: Comparison of the insertion loss determined from unchanged and leveled calculation results (according to Nord2000) in accordance with ISO 10847 at the receiver positions in Hettenkofen in relation to the four reference positions

Source: own graphic

However, except for the *Street low* reference position, it is also clear from the graphs that the deviations caused by the leveling process are negligible. Accordingly, the leveled values are used in the following.

Comparison of measurement vs. calculation

In order to examine the question of the effect of vegetation and photovoltaics on noise barriers, the insertion loss from measurement and calculation was determined. Figure 4 shows the results at the five receiver positions for the measurements and calculations according to RLS-19 and Nord2000 at the cross-sections in Hettenkofen and Töging (without and with PV) for all four reference positions.

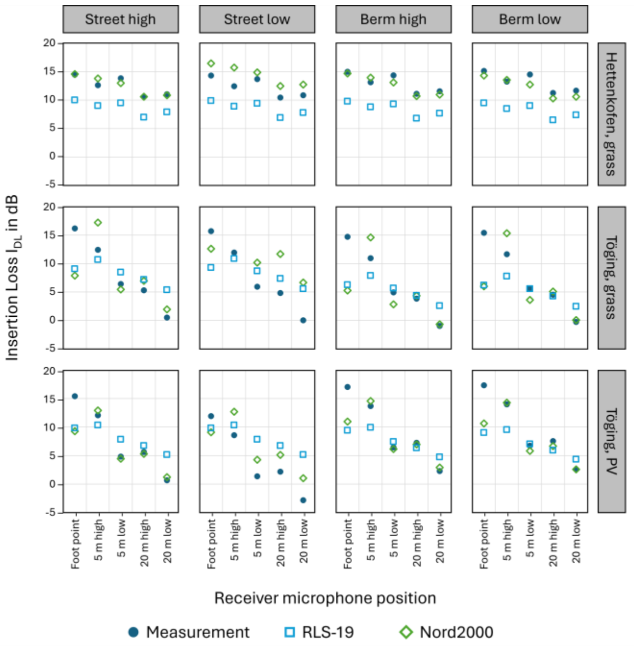

Figure 4: Comparison of the insertion loss determined from measurement and calculation (according to RLS-19 and Nord2000) according to ISO 10847 at the receiver positions in Hettenkofen and Töging (without and with PV) in relation to the four reference positions

Source: own graphic

In Hettenkofen, there is very good agreement between measurements and calculations according to Nord2000 for the reference positions *Street high* and *Berm high*. In contrast, the calculations according to RLS-19 provide significantly lower insertion losses (3 dB to 5 dB). As the insertion losses are level differences that all relate to the measured value at the *Street high* reference point due to the level control, the RLS-19 provides higher rating levels than the measurements show. The RLS-19 thus calculates to the safe side.

The cross-sections in Töging show both greater deviations between the measurements and the calculations as well as a fundamentally different behaviour of the insertion loss across the receiver positions. The reason for this is probably due to the trough location of the highway, the 1.5 m high wall on the top of the embankment and the deviations between the reference cross-section and the cross-section on the embankment as well as the resulting measurement positions (see Figure 2).

It is unusual that the insertion loss from the measurements at the lower receiver positions (5 m low and 20 m low) is lower than at the higher ones, and at 20 m low it assumes negative values in some cases. As the cross-sections under consideration are troughs, the insertion loss does not only reflect the influence of the embankment, but also the effect of the cut and the wall on the top of the embankment and, if applicable, different wind conditions. It is therefore not possible to draw any meaningful conclusions about the effect of the vegetation and the PV on the embankment in Töging.

However, as the cross-section in Hettenkofen showed very good agreement between measurements and calculations according to Nord2000, the sound propagation behind the noise barrier will only be considered analytical in the next step. This also has the advantage that larger distances to the embankment can be investigated. In most cases, it is no longer possible to generate usable results from measurements at large distances.

Comparison of Nord2000 vs. RLS-19

Noise section maps were generated to compare the sound propagation behind the noise barrier in the two calculation regulations. Figure 5 shows the sound propagation from the closest lane to approx. 20 m behind the noise barrier for the Nord2000 (colored) and the RLS-19 (white). Both calculations are again leveled to the corresponding measured value at the reference position *Street high*. It can be seen that the sound propagation up to the embankment is similar. Only at the base of the embankment facing the street does the Nord2000 provide a more detailed result, which takes the ground effect more into account.

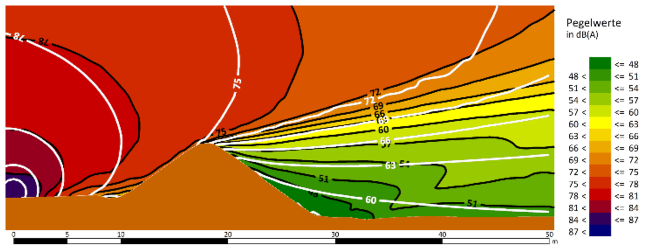

Figure 5: Comparison of the sound propagation up to a distance of 50 m from the first lane at the embankment cross-section in Hettenkofen without PV, calculated according to Nord2000 (colored) and RLS-19 (white)

Source: own graphic

Behind the noise barrier, however, the sound pressure level in the calculations according to Nord2000 decreases significantly faster than according to RLS-19. Close to the ground, the values according to RLS-19 are between 9 dB and 12 dB above those according to Nord2000, at the height of the top of the embankment in the range of 6 dB to 9 dB.

If one considers the insertion loss (cross-section without embankment minus with embankment) resulting from the two calculation methods, the RLS-19 provides a clearly different behavior than the Nord2000. Figure 6 shows the corresponding level differences from the calculations according to Nord2000 (colored) and RLS-19 (white) for a distance of up to 250 m from the closest lane. Positive values represent a reducing effect due to the embankment.

While in the RLS-19 the lines of equal insertion loss run in increasing arcs from the top of the embankment to the bottom, according to Nord2000, upward sloping lobes are formed. This behavior according to Nord2000 is consistent with results from earlier investigations on embankment by Van Renterghem and Botteldooren (see Figure 5 in [8]).

The different shape of the isophones results in different deviations in the level difference according to RLS-19 and Nord2000 depending on the height above ground and distance to the embankment. At the height of the top of the embankment, the deviation between the two calculation rules is initially approx. 7 dB and becomes smaller with increasing distance. Overall, it can also be observed that the effect of the embankment is equalized with increasing distance in the calculation regulations.

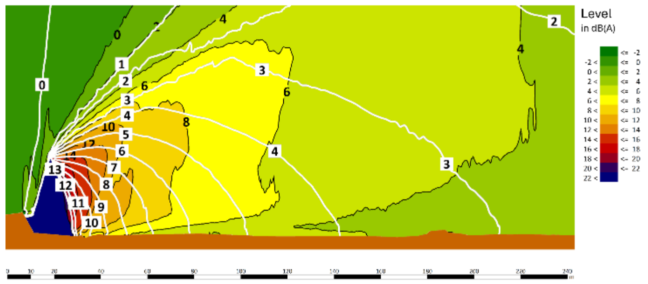

Figure 6: Insertion loss; representation of the level difference between the sound propagation at the cross-section in Hettenkofen with wall minus without wall, calculated according to Nord2000 (colored) and RLS-19 (white) up to a distance of 250 m from the first lane; elevation factor of the y-axis = 5

Source: own graphic

In order to investigate the effect of photovoltaics on the side facing the road, the difference between the same cross-section of the noise barrier in Hettenkofen with and without PV was calculated using Nord2000. As the software used for the calculations does not take into account reflections from inclined objects, the PV was only considered in the model as a sound-reflecting floor (impedance class G according to Nord2000).

Figure 7 clearly shows that two effects occur due to the PV. Firstly, some of the sound emitted by the traffic is deflected diagonally over the embankment in a narrow area by the reverberant ground. This effect causes increases of up to 2 dB and also influences the reference positions *Berm low* and *Berm high*. On the other hand, level increases of up to 3 dB occur in the shadow of the embankment.

With regard to the differences between the calculation results from RLS-19 and Nord2000, it can be stated that the level increase due to PV in the shadow of the embankment is significantly below the deviations between the calculations according to RLS-19 and Nord2000. The conservative results of RLS-19 thus cover the level increase due to PV in the vicinity of the embankment.

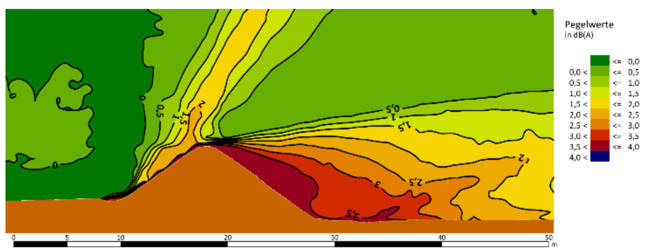

Figure 7: Representation of the level difference between the sound propagation calculated according to Nord2000 at the embankment cross-section in Hettenkofen with PV minus without PV up to a distance of 50 m from the first lane

Source: own graphic

Conclusion

The results of measurements and calculations on two embankments in Germany were presented in this study. The measurements were carried out in accordance with ISO 10847 to determine the insertion loss when using all types of outdoor noise barriers. The measurement results were compared with calculations according to the RLS-19 and Nord2000 and statements on the agreement between measurement and calculation were derived.

The results show that ...

… the RLS-19 determines higher sound levels in the shadow of the embankment than the measurement or the calculations according to Nord2000.

… the Nord2000 shows good agreement with the measurements in many areas.

… photovoltaics leads to a level increase of up to 3 dB in the shadow of the embankment.

… the effect of the embankment is equalized with increasing distance in the two calculation regulations.

In conclusion, it can be stated that RLS-19 calculates towards the safe side and also adequately covers the effects of photovoltaics on embankments.

Acknowledge

This report is based on parts of the research project carried out at the request of the Federal Ministry for Digital and Transport represented by the Federal Highway and Transport Research Institute, under research project No. 02.0454/2022/IRB.

The author is solely responsible for the content.

Literature

[1] F. Weinrich und Schierz, H., „Wirksamkeit von Lärmschirmen an 2- und 6-streifigen Straßenquerschnitten," Forschungsgesellschaft für Straßen und Verkehrswesen e. V. (FGSV), Köln, 2003.

[2] FGSV, Richtlinie für den Lärmschutz an Straßen - RLS-19, Köln: Forschungsgesellschaft für Straßen- und Verkehrswesen, 2019.

[3] J. Kragh, H. Jonasson, B. Plovsing und A. Sarinen, „User'S Guide Nord2000 Road," Hørsholm, 2006.

[4] „ISO 10847:1997-08 Acoustic . In-situ determination of insertion loss of outdoor noise barriers of all types".

[5] „ISO 9613-2:1996-12 Acoustic - Attenuation of sound during porpagation outdoors - Part 2: General method of calculation".

[6] B. Plovsing, „Nord2000. Comprehensive Outdoor Sound Porpagation Model. Part 1: Propagation in an Atmosphere woithout Significant Refraction," DELTA Danisch Electronics, Light & Acoustics, Hørsholm, 2006.

[7] B. Plovsing, „Nord2000. Comprehensive Outdoor Sound Propagation Model. Part 2: Propagation in an Atmosphere with Refraction," DELTA Danisch Electronics, Light & Acoustics, Hørsholm, 2006.

[8] T. Van Renterghem und D. Botteldooren, „On the choice between walls and berms for road traffic noise shielding including wind effects," *Landscape and Urban Planning,* Bd. 105, Nr. 3, pp. 199-210, 2012.