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Acoustic Effectivity of Old Noise Barriers

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ABSTRACT

Over time, different kinds of defects can appear at noise barriers. The presented project was meant to examine the influence of those defects on the acoustical behavior of noise barriers and to provide a catalog which enables the prediction of the influence of specific defects especially on the sound insulation of the noise barrier. Based on the information contained in the catalog, it should be possible to provide cost efficient action to permanently ensure the protection of immission sites.

To compile the catalog, the German sound propagation model of the RLS 90 has been extended by the description of the sound transmission through the noise barrier together with the geometrical consideration of leakages in the shape of holes and slits.

In the presentation it will be shown that the transmission coefficient of leakages can be predicted reliably by means of the calculation according to MECHEL as well as by measurements at noise barriers in situ. Furthermore, the latter ones have been used to successfully validate the models applied to describe the sound transmission coefficient of leakages and the sound propagation behind noise barriers in consideration of the transmission.

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1 INTRODUCTION

Noise barriers are used to shield immission sites like industrial or residential areas from unwanted noise. That is why it is of highest importance to be able to predicate the influence of defects at noise barriers on their acoustic effectivity at the relevant immission sites quickly and straightforward. Therefore, within the present project a method was developed that serves this purpose.

2 REVIEW OF LITERATURE

Due to the absence of overall investigations of this topic, already existing publications regarding the determination of the impact of constructional and aging defects on the acoustic effectivity of noise barriers were reviewed and discussed. It appeared that a multitude of references exist, which address subtasks of the project goal. The reviewed information deals with the possible compilation of a catalog of defects, with the acoustic description of such defects as well as with various methods to measure the transmission loss and the insertion loss of noise barriers with or without defects in situ and in the laboratory. It became apparent that the majority of previous investigations were carried out with satisfying accuracy at leakages that can be geometrically simply described, especially leakages in the shape of round holes and horizontally or vertically oriented slits.

3 SIMULATION OF SOUND FIELD

At noise barriers with assigned impedance being installed over ground with impedance discontinuity, very detailed sound field simulations can be carried out by applying a complex sound propagation model. In view of a future integration of the transmission characterizations into the nationally standardized propagation model of the RLS, the present model of the RLS 90 was implemented and extended to consider an additional transmission path through the noise barrier. Thereby, the incident cylindrical sound wave from the traffic flow (line source, see Figure 3.1) is transformed into a spherical wave behind the leakage within the noise barrier (point source) whose sound power is reduced due to the transmission through the noise barrier.

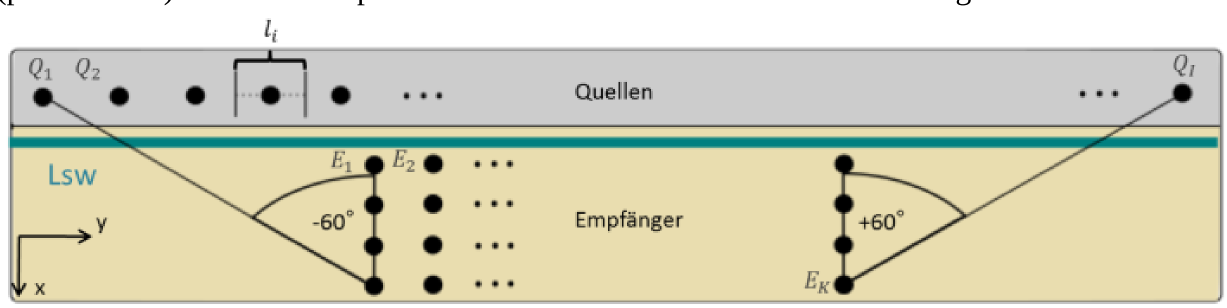

Figure 1: principle sketch of source and receiver positions considered within the simulations of the sound field along the noise barrier in top view; grey: road with source positions Q_i; green: noise barrier; beige: area with receiver positions E_k

The resulting model enables the calculation of the power of the sound wave transmitted through the leakage compared to the power of the sound wave diffracted around the top edge of the noise barrier. As a result, the influence of the leakage on the insertion loss of the noise barrier can be determined for arbitrary immission sites. Furthermore, by comparison of the power of the transmitted and the diffracted part of the sound wave, a simple criterion was defined that can be applied to get a fast and simple statement regarding the influence of the considered leakage behind the noise barrier.

The results of the sound field simulations showed the formation of an acoustically critical area behind the leakage. Within this area, the leakage has a relevant influence on the acoustic effectivity of the noise barrier, meaning that the immission sound pressure level increases by the presence of the defect in comparison to the immission sound pressure level behind the intact noise barrier. For this purpose, an analytical description of this overall condition GB was defined on the basis of the difference between the noise transmitted through the noise barrier and the noise diffracted around the top edge. Exemplarily, Figure 2 shows the calculated overall condition in a height of 2,8 m above ground in top view of a noise barrier with a height of 9 m and a leakage of 0,5 m² with a transmission coefficient of 0,4. In addition, the boundary of the acoustically critical area ($GB = 0$) that lies symmetrically around the leakage behind the noise barrier is marked in blue.

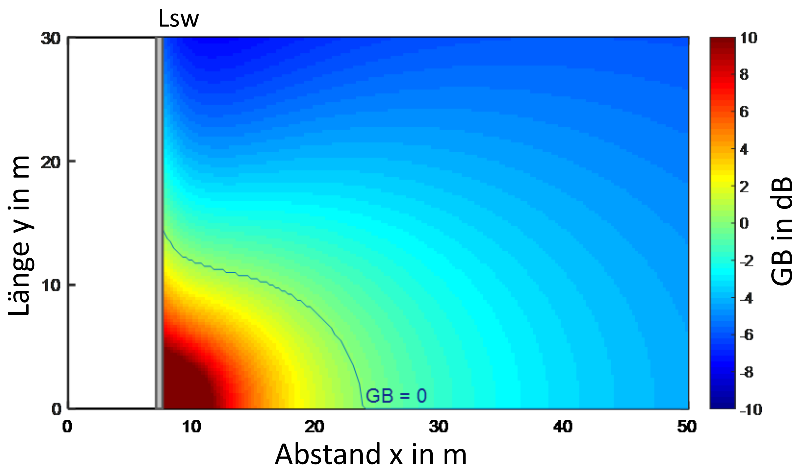

Figure 2: overall condition GB calculated in a height of 2,8 m above ground in top view of noise barrier with a height of 9 m and a leakage of 0,5 m² with $\tau = 0{,}4$; blue: boundary of acoustically critical area with $GB = 0$ symmetrical around leakage behind the noise barrier

It turns out that the influence radius of the leakage increases, the higher the noise barrier is, the closer the leakage is located to the ground and the higher the effective area (product of area and transmission coefficient) of the leakage is. By comparing the calculated influence radius to a zoning map, it is possible to prioritize the repairs of defects at noise barriers based on their acoustic properties.

4 ANALYSIS OF DEFECTS

An extensive analysis of defects at real noise barriers was performed. Afterwards, the different types of defects were classified concerning their acoustic relevance and were assigned to leakages that can be geometrically simply described, such as round holes and horizontally or vertically oriented slits. In Figure 3 typical defects at noise barriers are shown exemplarily.

Figure 3: diverse defects at noise barriers; from top left to bottom right: absent aluminum element of noise barrier, leakage in the shape of a slit due to absent ground sealing, slit due to absent sealing between concrete elements of noise barrier, holes in insulating material of a wooden noise barrier due to mechanical impact (sources: BMVI; Walloon Road Administration, Belgium)

In order to analytically describe the effect of such leakages on the acoustic properties of noise barriers, the implementation of the calculation model according to [MECHEL, 1986] was validated. By means of this model, the transmission coefficient of leakages in the shape of round holes and slits can be reliably predicted and further integrated into the propagation model developed above.

The geometry to determine the transmission coefficient of round leakages according to [MECHEL, 1986] is sketched in Figure 4 in lateral cross section. Thereby, a leakage with the diameter $2a$ and the length d is sealed on the front and the rear side by covering caps featuring the surface-related masses m_1 and m_2. Inside the leakage, a homogeneous, isotropic porous absorber is located characterized by the normalized propagation constant Γ_{an} and the normalized characteristic impedance Z_{an}.

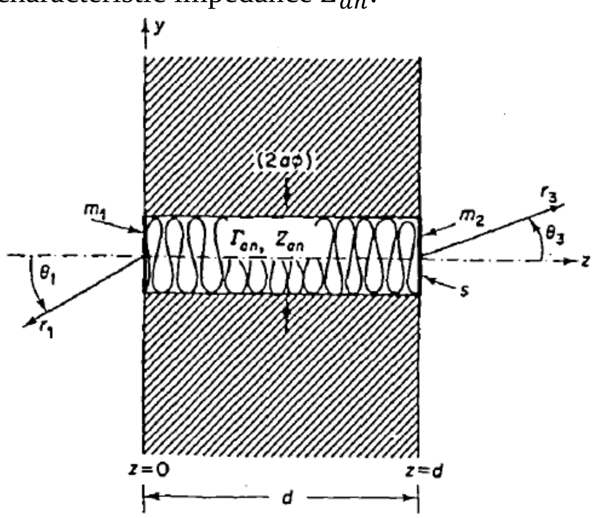

Figure 4: sketch of cross section of noise barrier with round leakage from [MECHEL, 1986]

5 MEASUREMENT OF TRANSMISSION LOSS AND SOUND ABSORPTION IN SITU

Within the project, measurements were performed in situ to determine the acoustic properties of noise barriers based on the “Adrienne Procedure” described in DIN EN ISO 1793-5 and DIN EN ISO 1793-6. In the first step, a test noise barrier was installed, in which geometrical exact leakages in the shape of round holes and slits were integrated. Figure 5 exemplarily shows the measurement setup for a leakage in the shape of a horizontally oriented slit in the test noise barrier.

Figure 5: setup for measurements at test noise barrier with geometrically exact leakages

The primary goal of the measurements in situ was to validate the calculation model of [MECHEL, 1986]. Figure 6 exemplarily shows the comparison of the transmission loss index *SI* of a horizontal slit and the simulated transmission loss according to [MECHEL, 1986]. A good agreement between the results of the measurement and the simulation is noticeable.

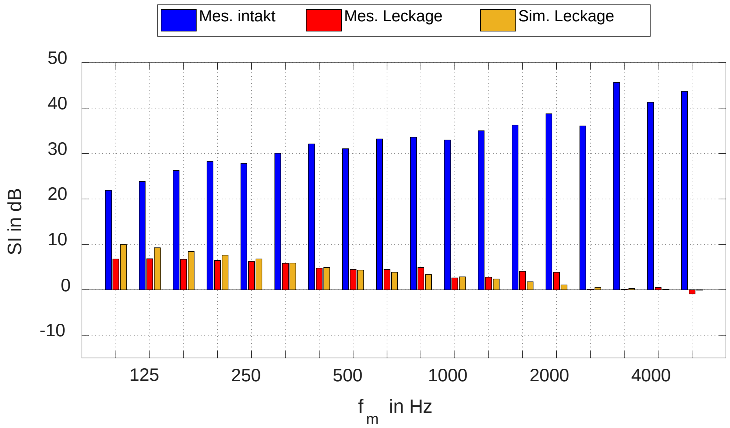

Figure 6: transmission loss of investigated noise barrier; blue: measurement result of intact noise barrier; red: measurement result of noise barrier with horizontally oriented slit; orange: simulation result of noise barrier with horizontally oriented slit

This requires the application of a defined correction function that considers the frequency-dependent “illuminated area” of the source-receiver geometry (see Figure 7) that is effective during the measurement in situ. This correction function defines the surface ratio of the leakage and the intact noise barrier within the total area that is illuminated during the measurement (Fresnel zone, see Figure 8).

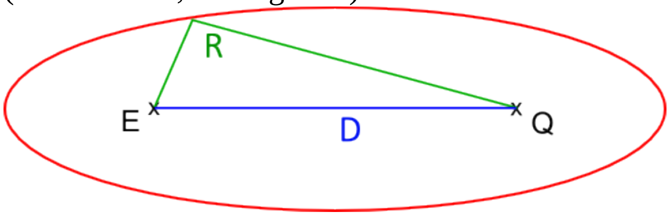

Figure 7: rotational ellipsoid with the focal points coinciding with the receiver (E) and the source (Q); D: distance between source and receiver; R: distance between source and receiver via circumference of ellipse

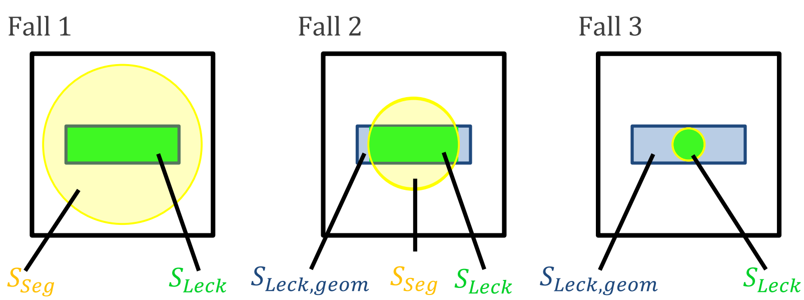

Figure 8: “illuminated area” S_{Seg}, geometrical area of leakage $S_{Leck,geom}$ and area of leakage to be considered S_{Leck} for three different cases at a leakage in the shape of a slit

Based on this correction function, it is possible to import values of the transmission loss of defect noise barriers measured in situ into the extended sound propagation model to further calculate the influence of defects on the immission sites behind the noise barrier. It was shown that for leakages that are very large compared to the “illuminated area”, a correction function of the transmission coefficient measured in situ is not necessary. By means of measurements in situ in greater distance to the noise barrier, the propagation model could be validated as well. In the range of the accuracy of measurement and model, a good accordance between the results of the measurement in situ and the sound field simulations was shown.

In a second step, measurements were performed in situ at chosen real noise barriers with real defects near motorways in the Free State of Saxony. Exemplarily, Figure 9 shows the setup for the measurement at a noise barrier with an approximately round leakage caused by mechanical impact. Here again, the calculation model according to [MECHEL, 1986] could be applied successfully to reproduce the results of the measurement in situ by means of simulation. Figure 10 shows a very good accordance between the transmission loss of the investigated glass noise barrier determined by measurement and by simulation.

Figure 9: test setup for measurement of transmission loss of noise barrier with defect in situ

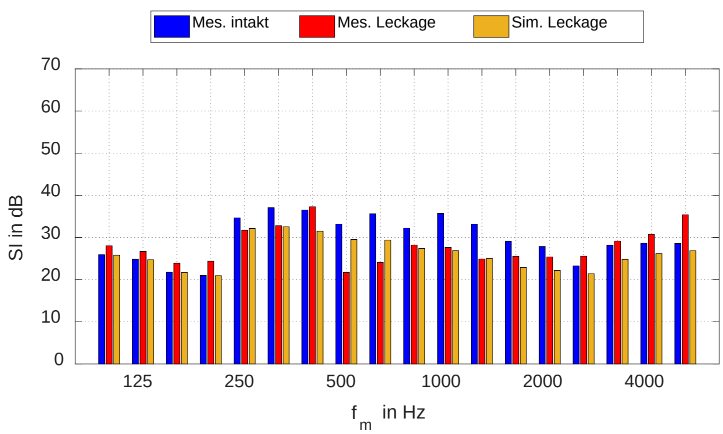

Figure 10: transmission loss of investigated glass noise barrier; blue: measurement result of intact noise barrier in situ; red: measurement result of noise barrier with leakage in situ; orange: simulation result of noise barrier with leakage; simulation parameters: $r_{Leck} = 45$ mm, $\rho_{AK} = 1{,}0\ \mathrm{g/cm^3}$, $d_{AK} = 0{,}5$ mm

However, it became apparent that the correct determination of the material-specific and the geometrical parameters of the leakages required for modelling the acoustic behavior (e.g. airflow resistivity of the absorber material, surface-related mass of rear covers, residues of interlayers, dimensions of unshaped defects) cannot be sufficiently achieved in all cases.

6 CATALOG OF DEFECTS

Based on the extended sound propagation model, a catalog of defects at noise barriers was provided. For this, leakages in the shape of holes and slits were considered as basic geometrical shapes for describing usual defects at noise barriers. As before, it was distinguished between horizontally and vertically oriented slits. In order to be able to evaluate a high multitude of defects, for round leakages an effective area (product of area and transmission coefficient), for slits an effective width (product of width of slit and transmission coefficient) was introduced as catalog parameter. Besides, the boundary of the acoustically critical area is visualized for different heights of the noise barrier from 3 m to 9 m as well as for varying heights of the leakage above ground. Exemplarily, Figure 11 shows the influence radius of a leakage in the shape of a horizontally oriented slit with a length of 4 m with different effective widths $\tau_L \cdot b_L$ in a noise barrier with a height of 5 m (in top view).

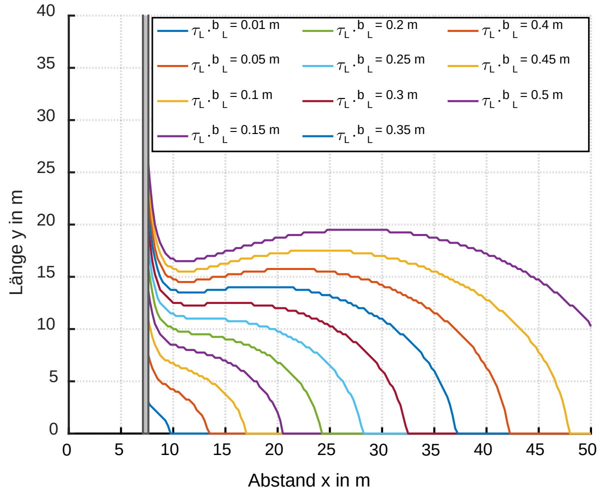

Figure 11: calculated effective radius of a leakage in the shape of a horizontally oriented slit with a length of 4 m and a varying effective width $\tau_L \cdot b_L$ in a noise barrier of 5 m height (in top view) for an average height of the leakage of 2,5 m

From now on, by applying this catalog, it is possible to evaluate the effect of existing leakages at noise barriers on the immission sound pressure level behind noise barriers based on their geometrical shape and position at the noise barrier. This allows the prioritization of repairs of defects at noise barriers based exclusively on the acoustic assessment. Furthermore, by means of the calculation model of [MECHEL, 1986], it is possible to predict the transmission coefficient of leakages in the shape of round holes and slits. Alternatively, especially in the case of complex leakages that are difficult to simplify regarding their geometry, measurements of the transmission coefficient at the defect area of the noise barrier can be carried out in situ. By means of the developed correction function regarding the “illuminated area”, the results of measurements in situ can be converted into an exclusive transmission coefficient of the leakage. For leakages whose dimensions exceed the diameter of the “illuminated area”, a correction of the transmission coefficient measured in situ is not required. The transmission coefficient obtained this way can be used to read the acoustical relevance of the considered leakage out of the catalog, by taking the effective area or the effective width of the leakage, respectively, into account.

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The author is solely responsible for the content.

5 REFERENCES

MECHEL, F., P.: The acoustic sealing of holes and slits in walls. Journal of Sound and Vibration, 1986