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Requirements for the façade sound insulation for different types of outdoor noise

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ABSTRACT

Buildings are exposed to a wide variety of external noise situations. The time course of the sound pressure level and the frequency response of external noise can vary greatly between the vicinity of roads compared to the vicinity of airports or railways.

The sound insulation of facades protect the indoor spaces and the residents against external noise day and night. The German standard DIN 4109 "Sound insulation in building construction" contains the minimum requirements for sound insulation for all new buildings in Germany. All requirements are based on a single-number-value, the equivalent sound pressure level, without adequate respecting to the particularities of the frequency response and time structure of a sound source.

The presentation shows the German standard values in building acoustics and the subject of external noise. The results of measurements of different sound sources will be shown. A new approach and an outlook for further possibilities to protect inhabitants appropriately to the noise situation will be discussed.

Keywords: façade sound insulation, building acoustics, outdoor noise

1. INTRODUCTION

In most countries, the façade sound insulation of residential buildings is determined as a function of the calculated external noise. External noise is calculated using the average traffic density of the nearby roads and railways as a single number value. In most cases annual average traffic volumes are used. Seasonal and daily fluctuations are not taken into account. Level fluctuations or maximum level during a single vehicle pass by or frequency characteristics are also not considered.

However, since the change of DIN 4109 (1) outside noise levels in the nighttime must be respected in Germany. This leads on average to an improvement of the façade sound insulation against external noise.

1.1 German standard DIN 4109

DIN 4109 "Sound insulation in building construction" (1) includes minimum requirements for the sound insulation for new building construction. In 2016, the standard was reissued. Since then, the standard consists of 4 parts dealing with various aspects of sound insulation. DIN 4109-1 "Minimum requirements" and 4109-2 "Computational proofs of compliance" have already been revised and republished in 2018.

A major deficit of the old DIN 4109 from 1989 was the inadequate protection in buildings from nocturnal noise. Since 2016 the outside noise levels in the nighttime must be taken into account in order to determine the façade sound insulation of buildings. As a result the requirements slightly increased for the majority of the construction projects in Germany.

2. PROTECTION OF INDOOR SPACES AGAINST OUTDOOR NOISE

2.1 Indoor sound level and protection level

For the maintenance of the psychomotor efficiency and health undisturbed sleep in sufficient duration is of central importance. Therefore the outdoor noise level must be considered, when constructing residential buildings in Germany. The calculation method of the façade sound insulation of DIN 4109 leads to an average indoor noise level of 35 dB during the daytime and 25 dB during the nighttime.

2.2 Day and night level differences

The level differences between day- and nighttime depend on the fluctuation of the traffic density. The Data of the noise mapping in Germany consists the calculated day-, evening- and nighttime level for a large number of streets and railways in Germany. For an assessment of the day and night level differences a data set of the noise mapping of 5 metropolitan areas in the federal state of Hessen was evaluated, which covers a total of approximately 1,600 kilometers of road and approximately 750 kilometers of railway. Figure 1 shows the day-night level differences of the roads. The day night-level differences for railway are shown in figure 2. Both figures are displayed as histogram with the investigated length of roads or railway.

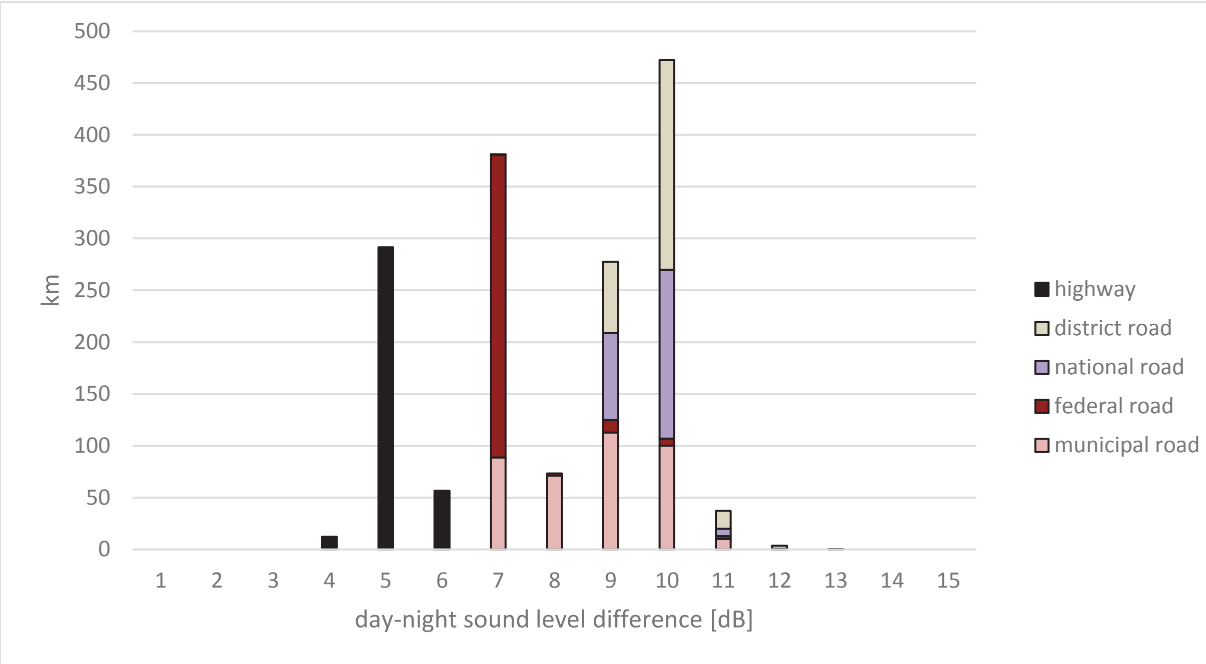

Figure 1 – Day and night level differences for road traffic

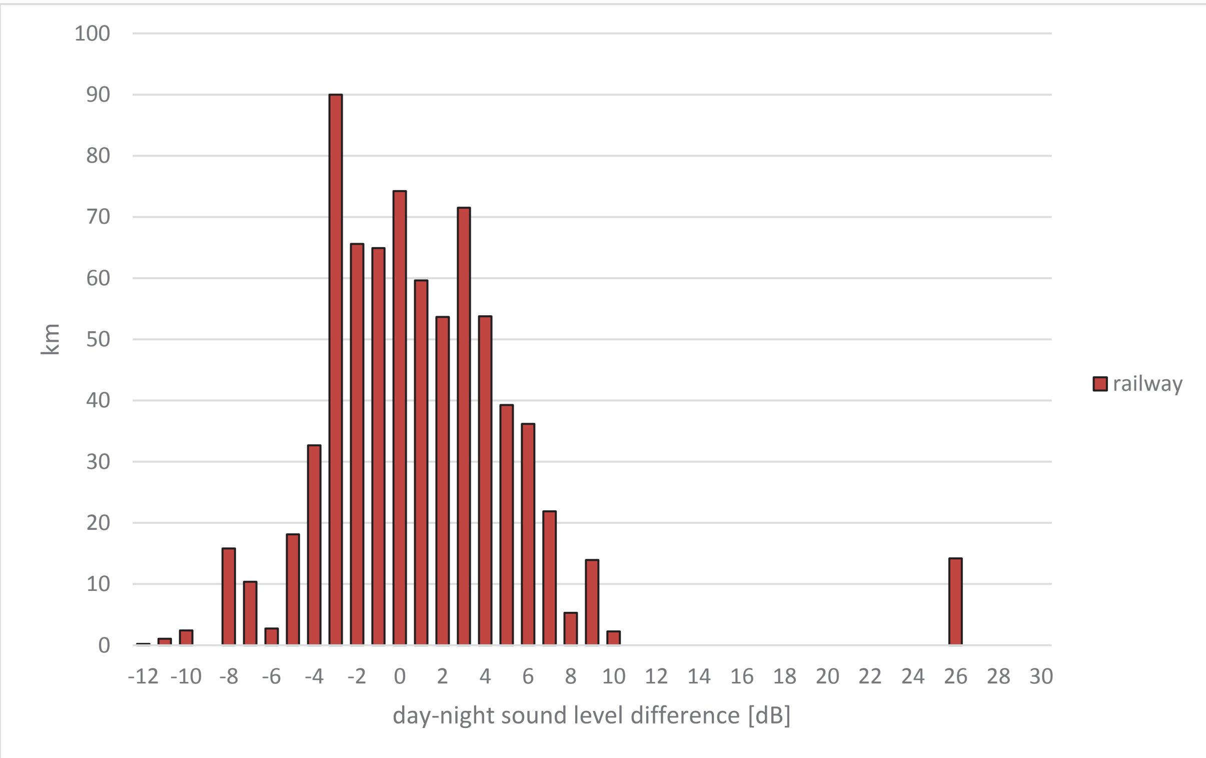

Figure 2 – Day and night level differences for rail traffic

The investigated day-night level differences strongly depend on the street category. The investigated highways show a much smaller day-night level difference than roads with usually less traffic like district roads or municipal roads.

The investigated railway lines show a much wider range and on average lower day-night level differences than the examined roads. The day-night level differences of the railway lines are mainly in the range -8 to 10 dB. On numerous railways, the nighttime period is even louder than the daytime period. This is mainly caused by the night freight train traffic. Very few of the investigated railway lines have no or very little rail traffic at night. These railway lines are summarized in Figure 2 with a calculated day-night level difference of 26 dB.

2.3 Seasonal and daily level fluctuation

The daily level fluctuation of traffic mainly depends on the street category and with it the task of the street in the surrounding street network. The sound level does not only depend on the amount of vehicles, but as well on the traffic mix of trucks, cars and motorcycles.

For an investigation of a road in the city of Karlsruhe in Germany the daily sound levels had been measured by the State Office for the Environment, Measurements and Nature Conservation of the Federal State of Baden-Württemberg (LUBW) over three years (2). The average sound levels for the weekday are displayed in Figure 3. As Figure 3 shows the measured sound pressure level beside the road vary during the daytime between 67 and 68 dB(A) in 2018. Average sound pressure levels on Saturdays and Sundays are lower than the sound pressure levels during the workdays from Monday to Friday, even when the differences are small.

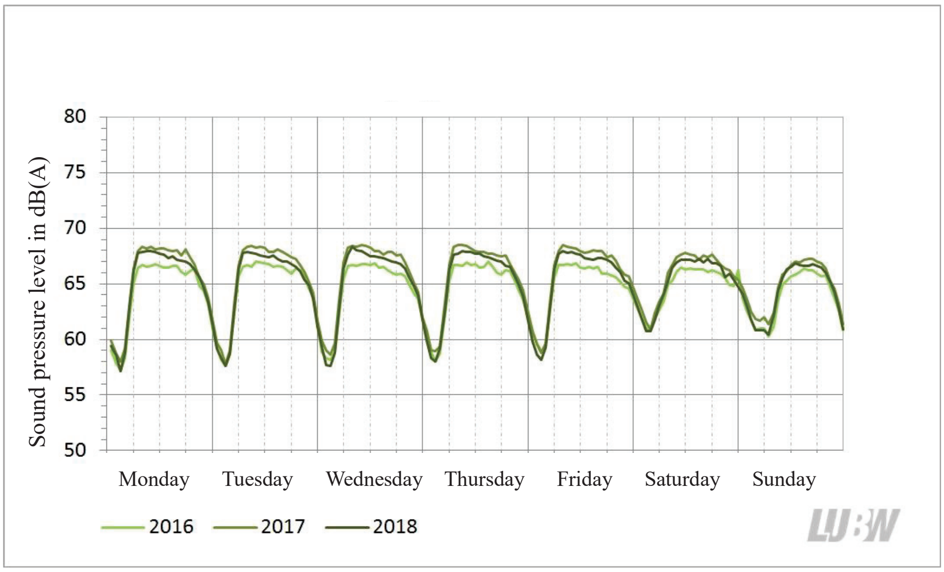

Figure 3 – Average Weekday fluctuation of the sound level at Reinhold-Frank-Straße in Karlsruhe (2) - modified

Figure 4 shows the results of the measurements of the LUBW (2) for the fluctuation of sound levels for the whole year period. Figure 4 shows the $L_{m,T}$ - the average sound pressure level for the daytime (6 am to 10 pm) - and the L_{DEN} - the average sound pressure level for the 24 h of a whole day, including day-, evening-, and nighttime.

During summertime the noise level measured beside the roads are slightly lower than during the wintertime. For example in 2018 the L_{DEN} varies between 66 dB(A) and 68 dB(A), while the L_{DEN} varies between 69 dB(A) and 71 dB(A).

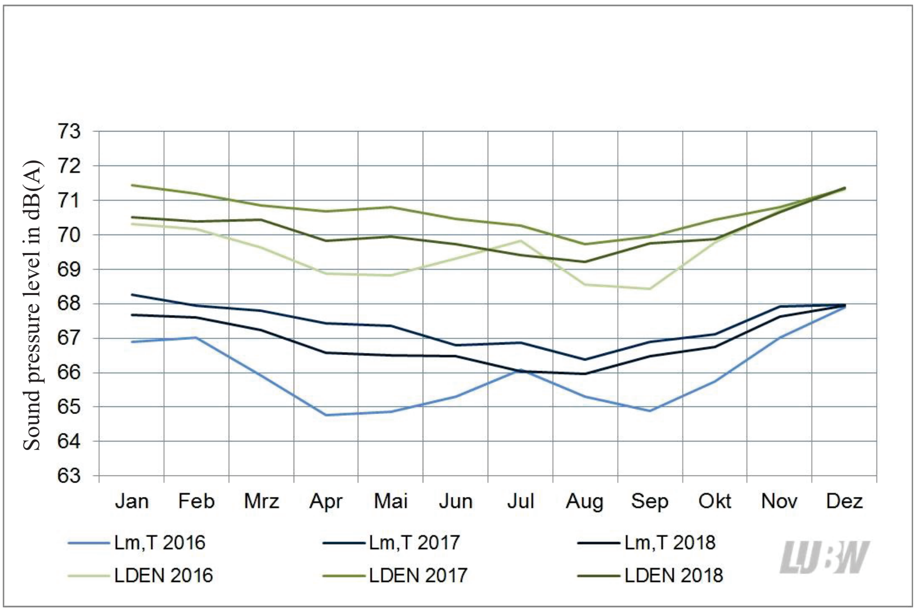

Figure 4 – Average yearly fluctuation of the sound level at Reinhold-Frank-Straße in Karlsruhe (2) - modified

2.4 Maximum sound pressure level during a vehicle pass by

The outdoor noise to which buildings a subjected is not an average year-, week- or day sound level. The outdoor noise underlies fluctuations within every vehicle pass by. Especially trains got in the focus of public discussion in Germany and a study of the Hessian Ministry of the Environment, Climate Protection, Agriculture and Consumer Protection (3) shows that fluctuating sound pressure level can lead to interruption of sleep and impair sleep quality. The indoor noise level can become sleep disturbing, especially when the façade sound insulation is determined to an average sound pressure level.

One way to describe the fluctuation of sounds is the comparison between the maximum sound level and the average sound level during a measurement period. The difference between maximum level and average level only depend on the sound source, but as well on the distance to the source. In Germany exist a large number of railway noise measurement stations. As an example in table 1 the measurement results of a measurement station based in the Hessian city Assmannshausen in the Middle Rhine Valley from 2018 (4) is shown. The measurement station is placed very close to the track in about 7 m distance. Data was provided by the Hessian Agency for Nature Conservation, Environment and Geology (HLNUG).

Table 1 – Average and maximum railway sound levels of the measurement station in Assmannshausen (4)

HLNUG Für eine lebenswerte Zukunft	Day		Night	
Month	L_{Aeq}	$L_{AF,max}$	L_{Aeq}	$L_{AF,max}$
Jun 18	71,9	98,8	74,6	99,3
Jul 18	72,0	99,0	74,4	98,7
Aug 18*	71,6	99,1	74,2	99,6
Sep 18	72,0	99,6	74,3	99,5
Oct 18	72,2	99,7	74,2	99,1
Nov 18	71,5	99,5	72,7	98,2
Dec 18	70,3	98,9	72,3	97,7

2.5 Frequency response

Beside the differences in time structure the frequency response of outdoor noise can vary widely. In conjunction with the frequency spectrum of façade components, as windows, the indoor level can be influenced because of the frequency signature of different sound sources.

The German standard DIN 4109 includes a 5 dB reduction to railway noise because railway traffic consists less low frequency noise than road traffic noise. In the last few years in Germany several investigations dealt with the topic of "spectrum corrections" and "spectrum adjustment values" (e.g. Schedl (5), Leupoldt (6) and Fischer (7)). Additionally the German standard VDI 2719 “Sound insulation of windows and their auxiliary facilities” of 1987 (8) contains spectrum adjustment values for façade sound insulation. The VDI 2719 shall be revised soon.

Schedl (5) investigated the spectral properties of more than 1,000 windows and summarized and categorized their frequency-related noise reduction measures. Leupoldt (6) determined the pass-by spectrum of about 500 trains at 9 locations and evaluated 140 overflights. Fischer (7) determined the spectrum of various road traffic situations at 8 measuring locations with approximately 60 20-minute measurements each. The results are summarized in Table 2 and divided according to the categories of VDI 2719 (8).

Table 2 – K-values and spectrum adjustment values comparison between VDI 2719 (8) and Fischer (7)

	VDI 2719	Fischer		
Immission points near…	K in dB	typ of window	average (rounded) in dB	maximum value in dB
railway lines with predominant Passenger transport	0	single	0	2,5
		box type		
other railway lines	3	single		
		box type		
inner-city roads	6	single	4	6
		box type	6	8,5
other roads	3	single	1	2
		box type	2	3
airports	6	single	7	11,3
		box type		

The comparison of the K-values for railway lines (all) and inner-city roads show, that there is a difference on average for single and box type windows of approximately 5 dB.

Other roads have only about 1 dB difference compared to rail lines. There is thus a difference of approximately 4 dB between inner-city roads and other roads. The reason given by Fischer is in particular the faster out-of-town speeds, which lead to a low proportion of low-frequency noise in the overall noise.

According to the results of Leupoldt, the spectral differences between freight traffic and passenger traffic are low on average. Routes with a train mix of freight and passenger traffic can thus be combined with routes with predominat passenger traffic.

3. CONCLUSIONS

The committee of the DIN 4109 has set up a working group, which deals intensively with the questions around the topic outdoor noise. The main task is the development of the existing regulations on façade sound insulation. Outdoor noise underlies a wide variation. Depending of the sources, distances or obstacles in the transmission path, the time and frequency structure of the outdoor noise influences the indoor noise.

In first investigations the night and daytime sound level differences could be determinated for different road types and trains. They show that the day-nighttime level differences often stay below 10 dB. With the goal of an average indoor sound pressure level of 35 dB daytime and 25 dB nighttime it is important to consider the night time noise levels to determine the necessary façade sound insulation.

A three year continuous measurement of road traffic noise of the LUBW (2) show that the daily, weekly and yearly fluctuations of noise have a negligible impact on the outdoor noise sound pressure level. The average fluctuation of the investigated sound level stays under 1 to 2 dB so the yearly average traffic intensity seems to be a good predictor for the calculation of outdoor noise sound pressure levels.

Measurements of railway noise of the HLUNG (4) show that the maximum sound pressure level and the equivalent average sound pressure level deviate largely in the vicinity of railway tracks.

The investigations by Schedl (5), Leupoldt (6) and Fischer (7) show that traffic noise can be much more differentiated in the determination of spectrum correction terms than currently specified in DIN 4109 or in VDI 2719. The consideration of a 5 dB correction sum due to the spectral composition of rail traffic is on average justified on the basis of the available studies on spectral characteristics of traffic noise sources in Germany.

However, this general consideration leads to a strong under- and over-dimensioning in the construction practice, because it is a strong simplification and summary of the actual spectral properties of the traffic noise and the sound insulation of the exterior components. A more detailed model could effectively reduce the under- or over-dimensioning of the sound insulation of the external façade.

Further research on the spectral and time related properties of various external noise situations is necessary as well as further investigations on the maximum sound pressure level.

ACKNOWLEDGEMENTS

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