The Acoustic Effectiveness of Low Height Noise Barrier

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ABSTRACT

The paper deals with the description and verification of a low height noise barrier (LHNB) applied along a 312 m section of a railway track (No. 240) in Tetcice. The LHNB application was used along a railway line in the Czech Republic for the second time. It is a low concrete structure of parabolic shape, fitted with a sound absorbing layer of synthetic recyclate and a thin layer of recycled rubber material. LHNBs are placed as close to the Z-GC maximum moving dimension as possible. The closest possible distance in the Czech Republic is 1.73 m from the rail axis. The LHNB was mounted at a distance of 2.00 m from the rail axis. A greater distance from the rail axis was conditioned on the possibility of the passage of rail vehicles exceeding the loading gauge. The verification of the LHNB efficiency was performed by direct in-situ measurement. Based on the measured data, a model of the investigated area was created in the LimA prediction software. NPHC was defined in the model at different distances from the rail axis. This model led to the determination of the influence of the distance from the rail axis on the acoustic situation.

Keywords: Low height noise barrier, railway, measurement, LimA

1. INTRODUCTION

Noise is one of the major factors affecting human health. Pursuant to Act No. 258/2000 Coll., On the Protection of Public Health, the provider of an activity whose by-product is undesirable noise is obliged to observe the noise limits specified in the Government Regulation No. 272/2011 Coll., On the Protection of Health from Adverse Effects of Noise and Vibrations [1]. Railway traffic, like the other traffic modes, is a significant source of noise and vibrations. Protection from the noise induced by rail traffic is possible by active noise control measures, which prevent the very appearance of noise (measures used in the traffic route construction or directly on vehicles) or by passive measures, which prevent the propagation of already existing noise (most frequently noise reduction walls). During the last twenty years, the construction of classic acoustic noise barrier walls (NBW) has been massively supported. At present, the development has concentrated on so-called low height noise barrier (LHNB). Thanks to their dimensions, compared to classic NBW, these LHNB can be placed much closer to the source of noise, and thus they are able to dampen rolling noise and noise from the bogie more reliably. Unlike classic NBW, low height noise barriers also have lower economic costs, easier handling, assembly and dismantling and allow easier access of security forces to the traffic route. It has generally been found out that the efficiency of LHNB is, in some cases, comparable to classic NBW, which are not very positively accepted by the public.

In the Czech Republic, BRENS® BARRIER low height noise barriers have already been applied on two sections along railway tracks. The first installation was carried out in Praha – Hlubočepy in spring 2013. It accounted for the reduction in noise emissions by ca 6.5 dB. The sound dampening value was identified based on measurements before and after the LHNB erection at a measuring point located on the side with the barrier, at a height of 0.5 m above the top of rail (TOR), at a distance of 7.5 m from the rail axis [2].

The second territory with the BRENS ®BARRIER LHNB application, which will be the topic of this article, is situated at Tetčice near Brno. Here, LHNBs was applied at the end of 2013.

Direct field measurement before and, successively, after the installation of low height noise barriers was carried out at three measuring points along the railway track within the investigated section. The measured values of the equivalent continuous sound pressure level A L_{Aeq} served to identify the acoustic efficiency of the newly applied low height noise barrier. The objective of the measurement was to identify the effect of LHNB at such points where we presume:

- a significant effect of the used LHNB,

- a negligible effect of the used LHNB.

The measurement methodology used specified the position of measuring points MP1 and MP2 in relation to the plotted curve showing the sound energy propagation from the source of noise below and above the level of this line.

Based on the data from the field measurement, a model of the investigated territory was created in the LimA prediction software. In the model, LHNB was defined at different distances from the railway track axis. This model served for the identification of the effect of the LHNB distance from the rail axis on the acoustic situation within the investigated territory.

2. BRENS® BARRIER LOW HEIGHT NOISE BARRIERS

Low height noise barriers (LHNB) are structures of the substructure, built for the purpose of limiting as much as possible the propagation of the noise arising at the wheel – rail contact into the surroundings. Therefore, the barriers are situated as close to the place of the noise generation, i.e. as close to the moving dimension as possible. In Praha – Hlubočepy, the barrier has been applied up to a distance of 1730 mm from the rail axis (Fig. 1), while in Tetčice it is situated at a distance of 2000 mm from the rail axis to allow the passage of freight trains exceeding the loading gauge (Fig. 2).

BRENS® BARRIER LHNB are composed of a set of parabolically curved concrete units complemented by a sound absorbing layer of recycled rubber (application in Praha – Hlubočepy), or by a combination of synthetic recyclate and a thin layer of rubber (application at Tetčice). Unlike standard high NBW, these barriers do not need special foundation structures, they are mounted on the footing bottom, on the substructure subgrade. BRENS® BARRIER LHNB have been developed in the Czech Republic in three types differing from each other by their height (0.55 m, 0.73 m and 0.90 m) and the absorbing layer structure. The currently used LHNB type is 0.73 m high above the top of rail (TOR). This LHNB type was chosen for its optimum size and absorbing layer efficiency with a simultaneous preservation of its safety performance. The LHNB upper surface is fitted with a roughened surface which can serve as an area for an emergency exit of passengers in the event

of an emergency.

Figure 1 Low height noise barrier in Praha Hlubočepy (on the left)

Figure 2 Low height noise barrier at Tetčice (on the right)

3. DESCRIPTION OF THE INVESTIGATED TERRITORY

In November 2013, a BRENS® BARRIER low height noise barrier (LHNB) was applied on a straight railway section of the railway line No. 240 (km of 6.075 – 6.391) at Tetčice near Brno. The length of the low height noise barrier itself is 316 m.

The single-track railway line No. 240 (Brno – Jihlava) is led on an embankment in this section. It has a standard rail gauge of 1435 mm. The superstructure is of a classic type, i.e. a plain line track bed of natural crushed stone of 31.5/63 mm grading. The track skeleton construction is composed of SB 8 concrete sleepers, onto which a rib soleplate with a ŽS4 rigid clamp is mounted by means of airscrews.

The S 49 flat-bottom rail is used there.

The railway line is operated by trains of three categories. The classification of train units into categories was performed on the basis of the Dutch RMR (SRM II) methodology described in the document: *Calculation of Noise from Railway Traffic: Manual 2013., ŠNAJDR, Karel. Praha 2013* [3].

The investigated railway line was operated by train units of the following categories:

Category 1 – slow trains with shoe brakes
Category 5 – diesel trains with shoe brakes
Category 6 – diesel trains with disc brakes

Category 5 was further subdivided according to the speed of passing trains into 5a and 5b, as this category includes both slow and fast trains.

The low height noise barrier was mounted on the right side of the railway track in the stationing direction. To allow the transport of carloads exceeding the loading gauge, the low height noise barrier (LHNB upper edge) was mounted at a distance of 2.00 m from the rail axis. In elevation, each segment is mounted so that its upper edge is 0.73 m above the top of rail.

4. FIELD MEASUREMENT

Pursuant to ČSN EN ISO 3095 – Measurement of Noise Emitted by Rail Vehicles [4], the measurement was performed at three measuring points before and after the LHNB installation. During the measurement, carried out simultaneously at individual measuring points, the equivalent continuous sound pressure level A L_{Aeq} was recorded during the passage of train units. The measurement at individual measuring points was performed simultaneously during the passage of one train unit. Meteorological conditions were recorded at the same time (air temperature, relative air humidity, barometric pressure and wind speed).

The position of measuring points MP1 and MP2 was identified in relation to the plotted curve describing the propagation of sound energy from the source of noise (Figure 3). The plotted curve is the diagonal line between two points where:

- Point P1 is placed in the rail axis (0.5 m above the connecting line of rail tops), i.e. at a height of the presumed dominant source of noise.
- Point P2 is the closest LHNB upper edge standing along the railway track.

Measuring point MP1 was placed at a sufficient distance below the plotted curve at a height of 0.2 m below the top of rail (TOR), at a distance of 6.5 from the rail axis.

Measuring point MP2 was placed above the plotted curve at a height of 1.7 m above TOR, at a distance of 6.5 m from the rail axis.

Measuring point MP3 is situated on the side without LHNB, at a distance and height pursuant to the technical standard [4], i.e. 1.2 m above TOR, at a distance of 7.5 m from the rail axis.

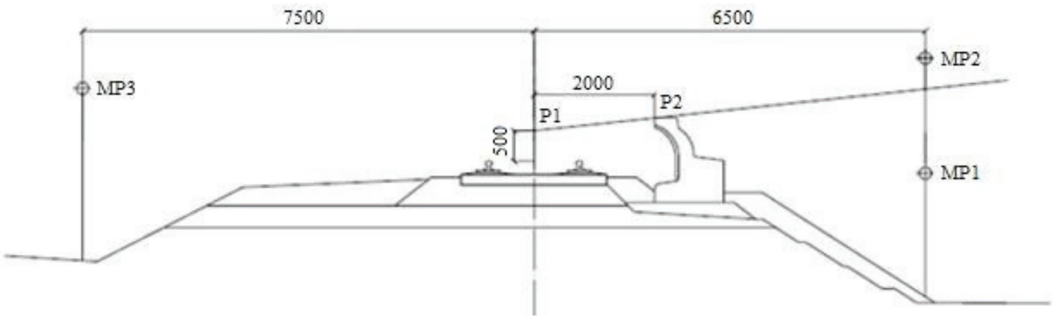

Figure 3 – Position of measuring microphones in relation to the track

Individual passages of train units were recorded during the measurement. At point MP1, a total of 19 passages of train units in both directions were measured before the LHNB erection. At point MP2, a total of 20 passages in both directions were recorded, and at point MP3 a total of 12 passages in both directions.

After the LHNB erection, a total of 19 passages were measured at point MP1, a total of 19 passages at point MP2 and a total of 14 passages at point MP3, always together for both directions.

4.1 Evaluation of field measurement data

The measured data were processed in the B&K Type 7820 Evaluator programme. Individual passages of train units were evaluated by choosing the time development periods where the equivalent continuous sound pressure level (emitted by the monitored train unit) had exceeded a value of $L_{Aeq(1s)} \geq 60$ dB. This criterion was selected on the basis of a sufficient distance from the residual sound recorded during the measurement. Due to the variety of passing train types, noise exposures A L_{AE} (sound energy related to a time period of 1s) were generated in the Evaluator programme for the comparison of noise emissions generated by the passage of a train unit. To increase the informative value the noise exposures A L_{AE} of individual passages were standardized according to the speed and the number of rail cars. Reference values of speeds and numbers of rail cars were identified separately for each category. Based on the Dutch RMR (SRM II) methodology [3], the train units were divided into individual categories (for more detail see chapter 3 *Description of the investigated territory*).

Table 1 below gives an overview of the resulting noise exposure values A $L_{AE,\ norm}$ at individual measuring points.

Table 1 – Comparison of LHNB efficiency at measuring points MP1, MP2 and MP3

	Measuring points - $L_{AE,\ norm.}$ [dB]		
	MP1	MP2	MP3
Without LHNB	96.0	96.3	95.7
With LHNB	88.4	92.7	96.1
Difference in noise emission	7.6	3.6	-0.4

The values reached at measuring points MP1 and MP2 confirm the initial assumption about reaching a lower sound pressure level at point MP1, lying in the acoustic shade of LHNB. The difference between the damping values at the points situated at a vertical distance of 1.9 m from each other, however, is not as significant as was expected. A damping of 3.6 dB at measuring point MP2, where a minimum difference in the values before and after the LHNB installation was presumed, could have been caused by partial absorption of the noise emission by the absorptive layer placed on the LHNB inner side. The measurement uncertainty corresponds to a value of ± 2dB.

To obtain more detailed information about the damping rate the results were divided into individual categories of rail vehicles according to [3]. Table 2 presents the resulting noise exposures at individual measuring points for the above categories of train units.

Table 2 – Comparison of LHNB efficiency at measuring points MP1, MP2 and MP3 for individual categories

	Measuring points classified into categories - $L_{AE,\ norm.}$ [dB]											
	MP1				MP2				MP3			
	Cat. 1	Cat. 5a	Cat. 5b	Cat. 6	Cat. 1	Cat. 5a	Cat. 5b	Cat. 6	Cat. 1	Cat. 5a	Cat. 5b	Cat. 6
Without LHNB	96.5	95.6	100.4	92.8	97.0	95.8	100.9	93.6	98.1	95.1	100.9	92.1
With LHNB	89.5	87.4	91.8	84.5	93.6	92.7	95.2	89.4	97.6	95.2	97.6	94.6
Difference in noise emission	7.0	8.2	8.6	8.3	3.4	3.1	5.7	4.2	0.5	-0.1	3.3	-2.5

Category 1 – slow trains with shoe brakes
Category 5a – diesel trains with shoe brakes (slow trains)
Category 5b – diesel trains with shoe brakes (fast trains)
Category 6 – diesel trains with disc brakes

Due to a relatively low number of measured passages after the classification into individual categories, it cannot be unambiguously identified for which category of rail vehicles the LHNB application is the most suitable noise control measure within the investigated territory. The results in Table 2, however, indicate a positive trend in the LHNB application at measuring point MP1 situated in the acoustic shade of LHNB.

5. MODEL IN LIMA SOFTWARE

A model of the territory along the railway line No. 240 (Brno – Jihlava) km 6.000 – 6.400V was created in the LimA prediction software according to the real situation. The objective of modelling in the LimA software was to find out the effect of the low height noise barrier (LHNB) distance from the rail axis on the resulting damping value. The comparison was performed at collection points situated 2 m in front of the façade of a residential building standing below the railway track embankment. Two collection points, SP 1 and SP 2, were created in the LimA software, at a distance of 18 m from the railway track axis, at a level of the centre of a window on the ground floor and the first overground floor, i.e. at heights of 1.6 m and 4.6 m above terrain.

The basic model in the LimA software was created without noise control measures (NCM). The background for the 3D model computation were ZABAGED® digital data (planimetry and altimetry) [5]. The contour lines and the railway body embankment had to be modified to correspond to the real situation identified during a field investigation. Another background document for the model complementation with buildings or other missing elements in the layout was the orthophoto map, which improved orientation in the model. Subsequently, LHNB was defined at a total of nine distances. The verification covered the distances of LHNB already applied in the Czech Republic, i.e. 1730 mm and 2 000 mm from the rail axis, and, furthermore, distances of 2 100 mm, 2 200 mm, 2 300 mm, 2 400 mm, 2 500 mm, 3 000 mm and 3 500 mm from the rail axis. The defined LHNB element reaches a height of 0.73 m above the top of rail (TOR). The parabolic arch found in BRENS® BARRIER LHNB cannot be precisely modelled in the LimA software. To preserve maximally the similar characteristics of the barrier, an element with a coping cranked in the direction towards the track was created. It is a concrete structure fitted with an absorptive layer of synthetic recyclate and a thin layer of recycled rubber material in the direction towards the railway track. The BRENS® BARRIER LHNB was defined as an "absorbing barrier" in the software with the parameters of reflectivity R= 0.35 and sound absorption A = 0.65.

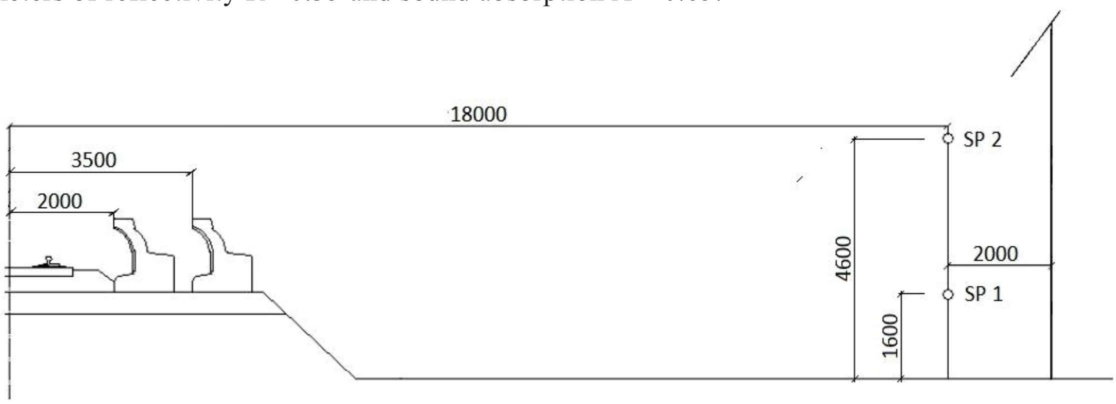

Figure 4 – Position of collection points

To be able to model the situation at the time of a train unit passage, the model was processed to consider one passage of a train unit after another. For this simulation, a time period of the passage of a train unit was selected (from the moment when the train unit front is in the axis of the measuring microphone to the moment when the rear of the train car is in this axis). The time period T was defined from the length of a passing train unit (according to the type of train and the number of cars) and the speed recorded during the field measurement.

$$T = \frac{l_{vs}}{v_{sk}} \tag{1}$$

where:

T time period [s],
l_{vs} train unit length [m],
v_{sk} real measured speed [m/s].

To verify the effect of the LHNB distance from the rail axis, the evaluation was made at collection points SP1 and SP2 for all categories operated on the investigated railway track.

The defined numbers of train passages in the day time according to solved categories, including standardized speeds:

Category 1: slow trains with shoe brakes (fast trains): 9 600 cars, 65 km/h,
Category 5a: diesel trains with shoe brakes (slow trains): 11 520 cars, 57 km/h,
Category 5b: diesel trains with shoe brakes (fast trains): 9 600 cars, 65 km/h,
Category 6: diesel trains with disc brakes (slow trains): 19 200 cars, 57 km/h.

The table below presents the values of equivalent continuous sound pressure levels L_{Aeq} at the time of the passages of train units of *Category 1* for individual distances of LHNB from the rail axis. The charts in Figs. 5 – 8 were made for better orientation in the results manifesting the damping rate in relation to the distance of a used noise control measure from the rail axis.

Table 3 – Effect of LHNB distance on acoustic situation - *Category 1*

LHNB distance from rail axis	SP 1 1.6 m above terrain 18 m from rail axis L_{Aeq} [dB]	SP 2 4,6 m above terrain 18 m from rail axis L_{Aeq} [dB]	Damping value SP 1 L_{Aeq} [dB]	Damping value SP 2 L_{Aeq} [dB]
Without LHNB	70.6	73.0	-	-
1730	59.9	63.0	10.7	10.0
2000	59.9	63.1	10.7	9.9
2100	60.1	63.3	10.5	9.7
2200	60.2	63.5	10.3	9.2
2300	60.3	63.8	10.3	9.2
2400	60.4	64.0	10.2	9.0
2500	60.5	64.2	10.1	8.8
3000	61.0	65.2	9.6	7.8
3500	61.5	66.1	9.1	6.9

The graphic evaluation of the effect of the LHNB distance on its efficiency at collection points SP1 and SP2 was processed for all solved categories.

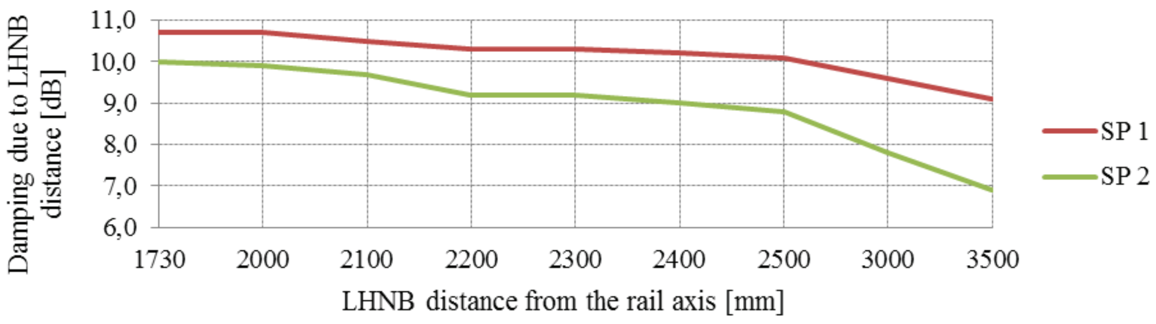

Figure 5 – Effect of the LHNB distance on acoustic situation - *Category 1*

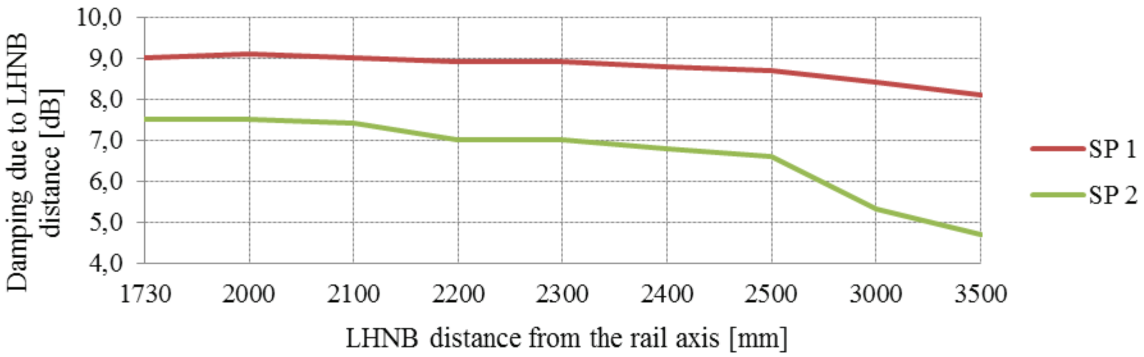

Figure 6 – Effect of the LHNB distance on acoustic situation - *Category 5a*

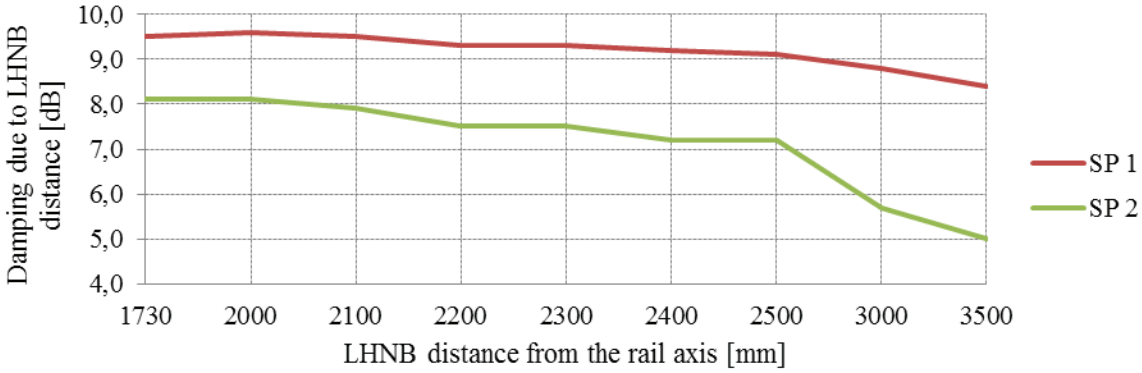

Figure 7 – Effect of the LHNB distance on acoustic situation - C*ategory 5b*

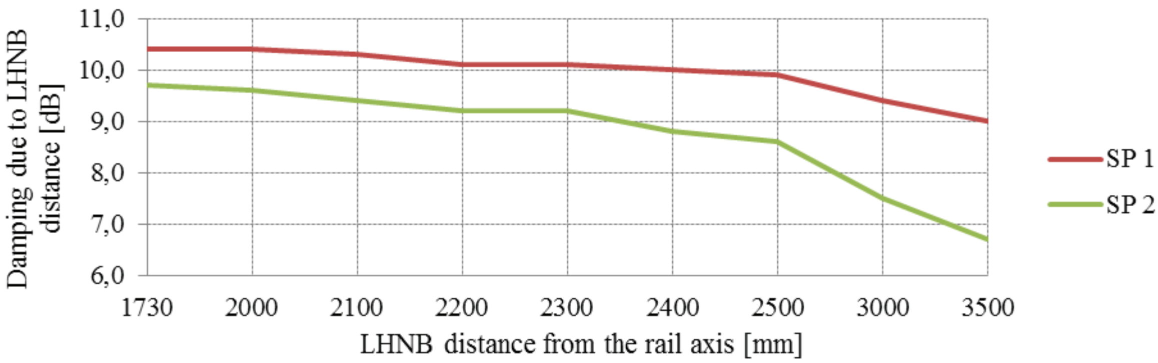

Figure 8 – Effect of the LHNB distance on acoustic situation - C*ategory 6*

The charts above clearly show that the effect of the LHNB distance from the rail axis at collection point SP1 situated 1.6 m above terrain is only insignificant. At a twice longer distance of LHNB from the rail axis (from 1730 mm to 3500 mm), the damping value only falls by 1 – 1.5 dB. At collection point SP2 situated 4.6 m above terrain, the effect of the LHNB distance from the rail axis was manifested by a value of around 3 dB in four evaluated categories at a twice longer distance of LHNB. The computational uncertainty in the LimA software was identified as ± 2dB.

6. Conclusion

The verification campaign of the efficiency of a low height noise barrier (LHNB) included direct field measurement when the damping value was identified at three measuring points along the railway track. At measuring point MP1, a point below the level of the curve manifesting the sound energy propagation from the source of noise, a damping value of 7.6 dB was reached. The damping of 3.6 dB, which was identified at measuring point MP2, where a minimum difference in the values before and after the LHNB installation had been presumed, could have been caused by partial absorption of the sound energy propagating from a train unit into the absorptive material found on the LHNB inner side during its passage.

A model of the investigated territory was created in the LimA software, where the effect of the LHNB distance from the rail axis on its efficiency was identified at collection points SP1 and SP2. At collection point SP1, situated 2 m in front of the façade of a building, at a height of 1.6 m above terrain, the damping value only differed by 1-1.5 dB at a twice longer LHNB distance from the rail axis, whereas at collection point SP2, situated 2 m in front of the façade of a building, at a height of 4.6 m above terrain, the damping value differed by 3 dB under the same conditions. It ensues from the model that the LHNB efficiency falls with the growing distance of its position from the rail axis depending on the height of the recording point.

7. References

[1] Government Regulation No. 272/2011 Coll. On Health Protection against Adverse Effects of Noise and Vibrations. In: . 2011.
[2] ČÍŽKOVÁ, Petra. Analysis of the Efficiency of a Low height noise Barrier in the Hlubočepy – Rudná Railway Line Section. Praha, 2013. Diploma thesis. ČVUT v Praze (In Czech).
[3] ŠNAJDR, Karel. Calculation of Noise from Railway Traffic: Manual 2013, Praha 2013 (in Czech)
[4] ČSN EN ISO 3095: Railway Applications – Acoustics – Measurement of Noise emitted by Rail Vehicles, March 2014.
[5] ZABAGED® - Planimetry and Altimetry 3D. Praha: ČUZK, 2007.