

Alžbeta PULTZNEROVÁ, Libor IŽVOLT¹

RAILWAY NOISE EMISSION ABATEMENT BY APPLICATION OF RESILIENT COMPONENTS TO THE PERMANENT WAY

Summary. The constantly increasing intensity of transport together with the increasing sensibility of population to noise load and air pollutants force the railway route owners and operators to implement effective measures to reduce negative effects of transport on its surroundings. Although the railway traffic is more environmentally friendly than road or aircraft traffic, the modernisation of railway corridors and the increase of the passing train speed causes the increase of the noise emissions, too.

This paper deals with the possibilities of abatement of the railway noise emissions directly at the source of the noise by resilient components built in the permanent way. They cause the vibration abatement of the passing trains and influence the transmission and emission of noise emissions. With the help of the ArcGIS software with the ArcAkus module the noise propagation and the possible abatement of noise levels after embedding of the rail absorber are simulated in a chosen area of the modernised railway track.

Keywords. Modernised railway track, Equivalent sound pressure level, Noise map, Rail noise absorber

REDUKCJA POZIOMU HAŁASU W RUCHU KOLEJOWYM PRZEZ ZASTOSOWANIE ODPORNYCH SKŁADNIKÓW W KONSTRUKCJI TOROWISKA

Wciąż postępujący wzrost natężenia ruchu transportowego w połączeniu z rosnącą wrażliwością społeczną na emisję hałasu i zanieczyszczenie powietrza skłaniają właścicieli infrastruktury i operatorów do wdrażania skutecznych środków obniżenia negatywnego oddziaływania transportu na środowisko. Mimo iż ruch kolejowy jest bardziej przyjazny środowisku niż ruch drogowy czy też lotniczy, modernizacja kolejowych korytarzy transportowych i zwiększanie prędkości przejazdu pociągów przyczyniają się również do zwiększenia poziomu hałasu.

W niniejszym artykule przedstawiono możliwości zmniejszenia emisji hałasu bezpośrednio u jego źródła, poprzez zastosowanie w konstrukcji torowiska bardziej odpornych materiałów. Umożliwia to zmniejszenie wibracji pochodzących od przejeżdżającego pociągu, a co za tym idzie również redukcję poziomu emitowanego hałasu. Przy użyciu oprogramowania ArcGIS z modułem ArcAkus przeprowadzono symulację propagacji hałasu w wybranym obszarze modernizowanej sieci kolejowej oraz symulację dla tego samego obszaru, po zainstalowaniu elementów absorbujących hałas.

¹ Department of Railway Engineering and Track Management, Faculty of Civil Engineering, University of Žilina, Univerzitná 8215/1, 010 26 Žilina, Slovak Republic, tel. ++421-41-513 5813, e-mail: alzbeta.pultznerova@fstav.uniza.sk, libor.izvolt@fstav.uniza.sk

Słowa kluczowe. Zmodernizowana linia kolejowa, poziom hałasu, mapa hałasu, pochłaniacz hałasu kolejowego

1. INTRODUCTION

Generally accepted, traffic is one of the most important factors in environmental pollution. This also applies from the point of view of noise emissions. The railway traffic is more environmentally friendly than the road or air traffic and regarded as a noise source also loads less the inhabitants in the vicinity of railways.

The noise which is produced during the contact of a wheel with a rail is a dominant and crucial noise source of the railway transport. Nowadays, the modernisation of railway corridors in the Slovak Republic territory, that aims to set the track speed to $160 \text{ km}\cdot\text{h}^{-1}$, can cause the risk of noise emission increase, too. Considering the valid legislative document [1], it is necessary to work out the noise impact studies in the stage of design preparation of modernisation of corridor track sections. These studies are supposed to propose some noise reduction measures on the basis of noise prediction values in order to meet the permissible noise level limits declared in the respective legislative document.

In the long term perspective, the most standard way to reduce noise emissions is building of high noise barriers, which are effective in many cases, but often they do not represent sufficient measures. They possibly disrupt the landscape view, limit the view of the train passengers, or in the case of grade crossings they limit the driver's view, thus they may reduce the traffic safety. Therefore, it is advantageous to reduce the noise level directly in the place of origin as much as possible by suitable design of the railway vehicle bogies, or from the point view of the railway line construction by installation of various flexible elements and railway absorbers, which belong among so called active noise-reducing measures.

2. EXAMPLES OF NOISE REDUCTION BY APPLYING THE ANTI-VIBRATION AND DAMPER ELEMENTS TO THE SUPERSTRUCTURE

As pointed out in the previous text, nowadays the active noise-reducing measures to reduce the noise emissions caused by the traffic of the passing trains are mainly preferred. From this point of view, it is possible to apply more structural arrangements and structural elements. Using them it is possible to achieve various values of noise emission reduction depending on their effectiveness and place of application. The brief characteristics of some selected structural elements for reducing vibrations caused by rail traffic can be found below.

2.1. Antivibration pads and mats

By using antivibration mats and pads in the structure of the railway superstructure vibration and noise are reduced, depending on their placement. The individual application possibilities are shown in the Fig. 1 to Fig. 4 [3].

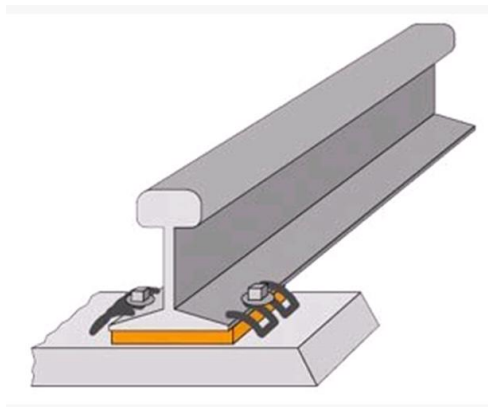


Fig. 1. Antivibration pad under rail
Rys. 1. Antywibracyjna podkładka pod szynę

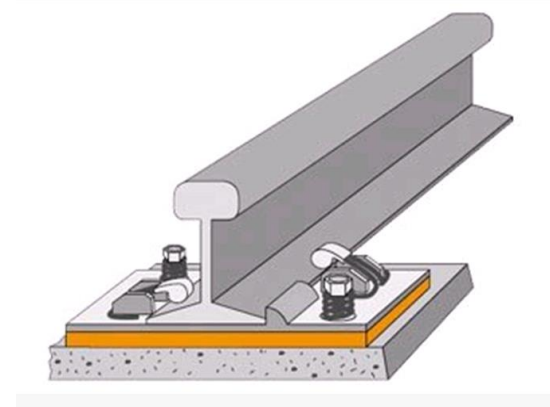


Fig. 2. Antivibration pad under baseplate
Rys. 2. Antywibracyjna podkładka nad podkładem

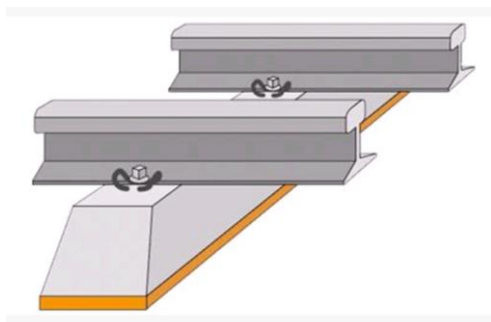


Fig. 3. Antivibration pad under sleeper
Rys. 3. Antywibracyjna podkładka

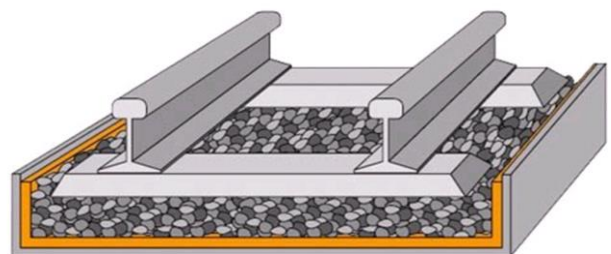


Fig. 4. Antivibration mat under ballast bed
Rys. 4. Antywibracyjna podkładka pod specjalnym podłożem

2.2. Possibilities of using damper elements in the construction of slab track

The slab track is a type of superstructure without any railway bed. The rails are fastened on a concrete plate or sleeper fastenings in a concrete bed. The cost of its establishment are higher (approximately 40 to 80%, depending on the type of structure and local conditions) than the costs of establishment of the classic superstructure design (track panel put on the railway bed). However, the maintenance costs are minimal and its lifetime is estimated to be 60 years. This structure is particularly applied on high-speed lines on bridges and in tunnels regardless of the railway line type. Its disadvantage is the fact that it is a source of larger noise emissions than in the case of the classic superstructure design and therefore it is necessary to apply some adjustments to reduce vibration as e.g. the antivibration pads, mentioned in the chapter 2.1., noise absorbers in the railway superstructure (Fig. 5) and other additional structural adjustments (Fig. 6).

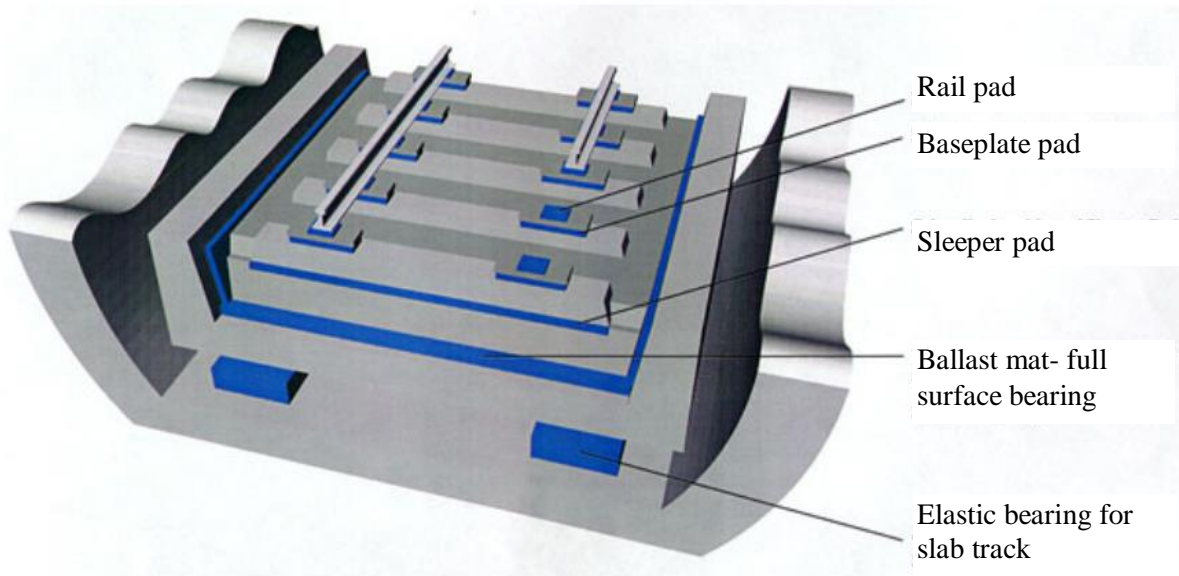


Fig. 5. Elastic elements built in the slab track superstructure [5]

Rys. 5. Elastyczne elementy wbudowane w płyty nawierzchni kolejowej [5]

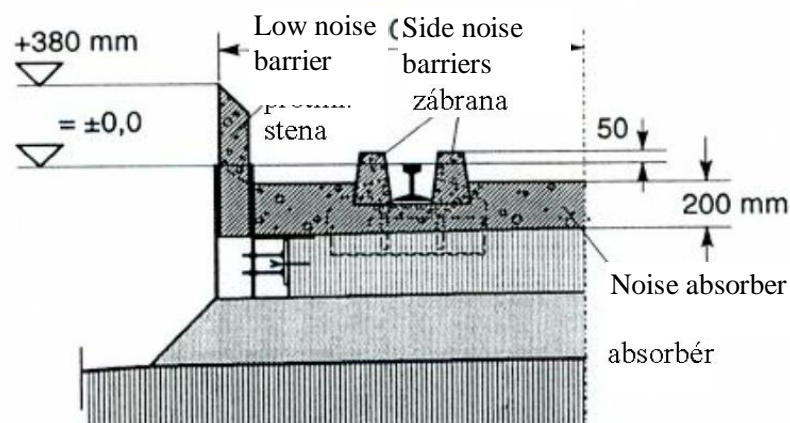


Fig. 6. Examples of noise abatement on slab track [6]

Rys. 6. Przykłady ograniczenia hałasu na torze [6]

2.3. The design of a railway line with reduced noise emissions

This structure is a special structure that in addition to the above mentioned applications for the reduction of noise emissions utilizes the combination of polyurethane and cork - so called *corkelast*. The structure of the so called *Silent Track* is applied in the slab track structures. In the Fig. 7 and 8 the cross section of the rail fastening with small emissions of noise is shown and the Fig. 9 shows the structure of a railway line in the Netherlands where the structural elements for the noise emission reduction were applied. In this case, the noise abatement of the tracks is caused by the continuously welded rails of rail profile *UIC 54*, which is embedded into the cork material – “corkelast”.

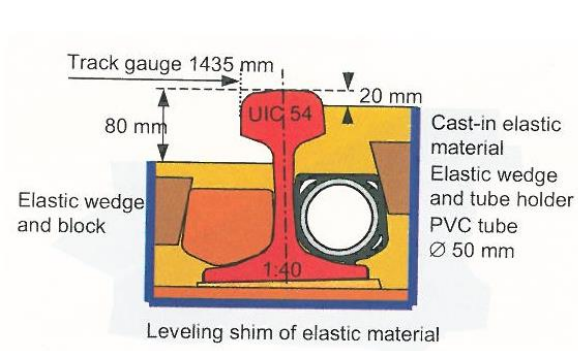


Fig. 7. Elastic fastening of rails UIC 54 inside the groove [7]

Rys. 7. Elastyczne mocowanie szyn UIC 54 [7]

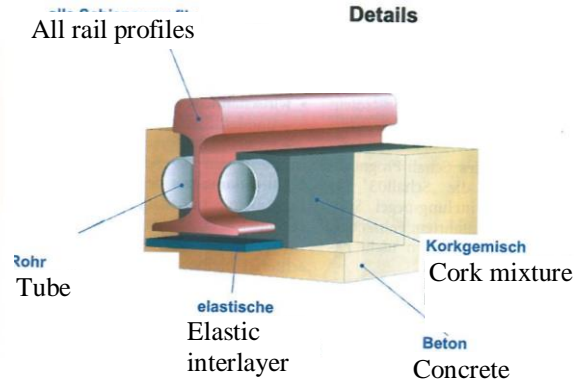


Fig. 8. Elastic fastening of rail FiL-Rail ERS [8]

Rys. 8. Elastyczne mocowanie szyn FiL-Rail ERS [8]

Within the research task *Stiller Treinverkehr*, initiated by the Danish government, the design proposal of *Silent Track* introducing the new rail profile *SA 42* was developed. In the project *Silent Track* the task was developing a new superstructure, which would reduce the noise level. The solution lied in the embedded rail structure in the relatively solid "corkelast", which is obvious in the Fig. 10. The rail profile *SA 42* has a weight of 42 kg. m^{-1} and its height is only 80 mm. This rail is able to bear 225 kN axle pressure and is quieter in 5 dB(A) compared to a conventional concrete slab.

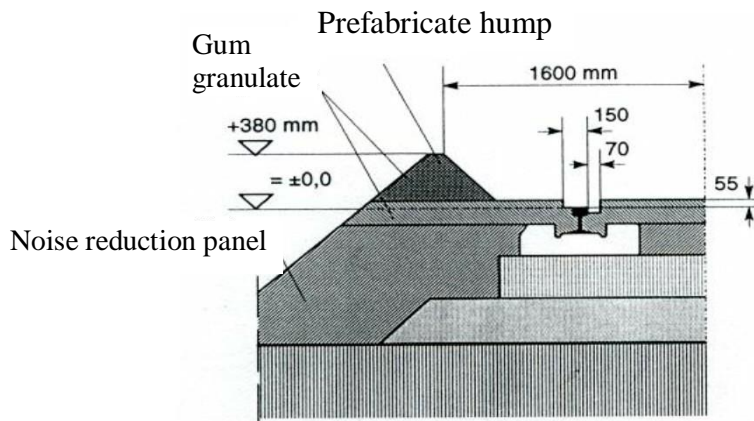


Fig. 9. Scheme of the „Silent Track“ in the Netherlands [6]

Rys. 9. Schemat „Silent Track“ w Holandii [6]

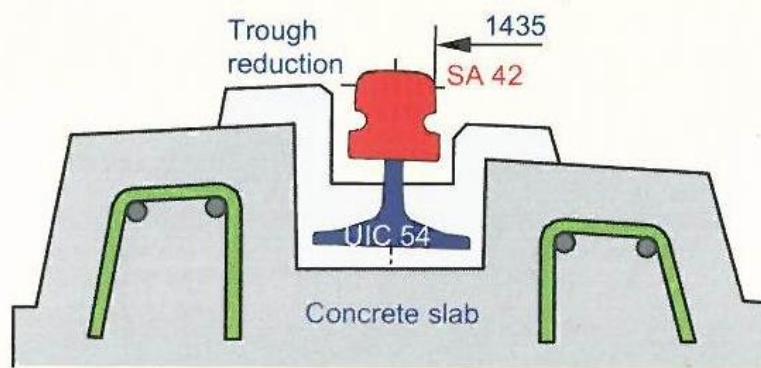


Fig. 10. Low-noise rail SA 42 [7]

Rys. 10. Szyna o niskim hałasie SA 42 [7]

2.4. Rail absorber

Similarly as in the case of the wheel absorber, by adding weight and increasing the damping coefficient faster reduction of the emerging vibration wave in the rail strip can be achieved (Fig. 11). The rail absorber has a sandwich structure and consists of a 5 mm thick metal cover connected to the filler material of high absorption properties (Fig. 12). It is fastened to the rail using special flexible glue and attached to it by clips. There are several industrially manufactured types, which are mainly used in the places where the density of the inhabitants in the railway line vicinity is higher and it is not possible to install the standard noise barriers due to insufficient area conditions or maintaining the prescribed view in the case of level crossings. The rail absorbers reduce the noise emissions by approximately 2 - 6 dB [6].



Fig. 11. Rail absorber [9]

Rys. 11. Absorbent szynowy [9]

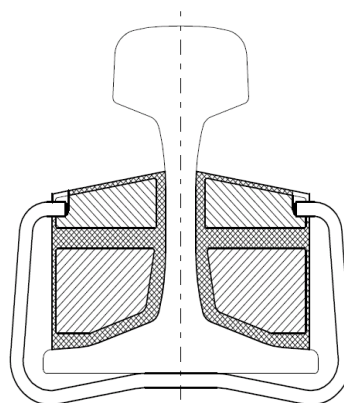


Fig. 12. Cross section of the rail absorber [9]

Rys. 12. Przekrój absorbenta szynowego [9]

Other types of track absorbers are shown in the Fig. 13 and Fig. 14, where the noise reductions by 5 dB are also stated.

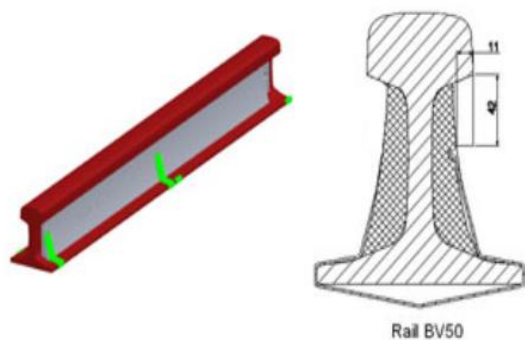


Fig. 13. Rail absorber for the rail of the type BV 50 and UIC 60 [10]

Rys. 13. Absorbent szynowy dla szyn typu BV 50 i UIC 60 [10]

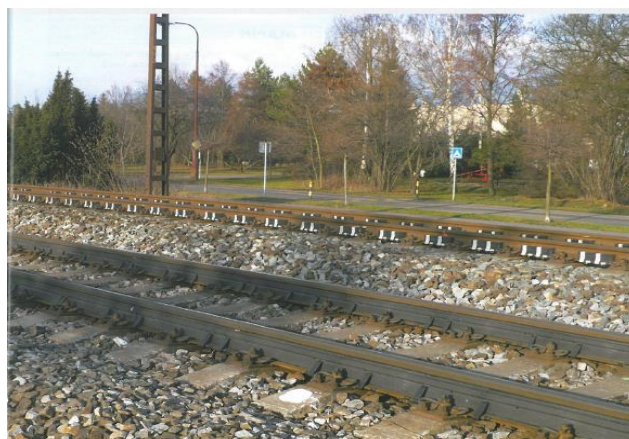


Fig. 14. Rail absorber Vossloh and Corus [11]

Rys. 14. Absorbent szynowy Vossloh i Corus [11]

3. CHARAKTERISTICS OF EXPERIMENTAL MEASUREMENTS ON THE SELECTED MODERNISED RAILWAY TRACK SECTION

To work out the noise map the modernised track section Trnava railway station - Nové Mesto nad Váhom railway station (railway kilometre 47.550 – 100.500) was chosen. The reason for the selection of this section was that the noise abatement arrangements (noise barriers – PHS) were built there. The measurements were carried out in the shielded places by PHS 19 in the railway kilometre 80.499 091 – 80.841 526 at the rail No.1 in the locality Piešťany town (Fig. 15).



Fig. 15. View of the noise barrier

Rys. 15. Widok bariery zapobiegającej rozchodzeniu się hałasu

The measurements of the equivalent noise pressure levels $L_{Aeq,8h}$ were done in the chosen area during the night time (22:00 hod.- 6:00 hod.). The measurements were realised by the sound analysers *Norsonic* in the points **M1**, **M2** and **M3** from 22.05.2008 to 23.05 [12]. The characteristics of the measurement points M1, M2 and M3:

- M1** – 2 m in front of the window of the room on the 3rd floor of the residential house no. 33, M. Bela Street, Piešťany town, approximately 105 m from the track no. 120 (Fig. 16).
- M2** – 2 m in front of the window of the room on the 9th floor of the residential house no. 36, M. Bela Street, Piešťany town, approximately 88 m from the track no. 120 (Fig. 17).
- M3** – 2 m in front of the window of the room on the 3rd floor of the residential house no. 36, M. Bela Street, Piešťany town, approximately 88 m from the track no.120 (Fig. 18).

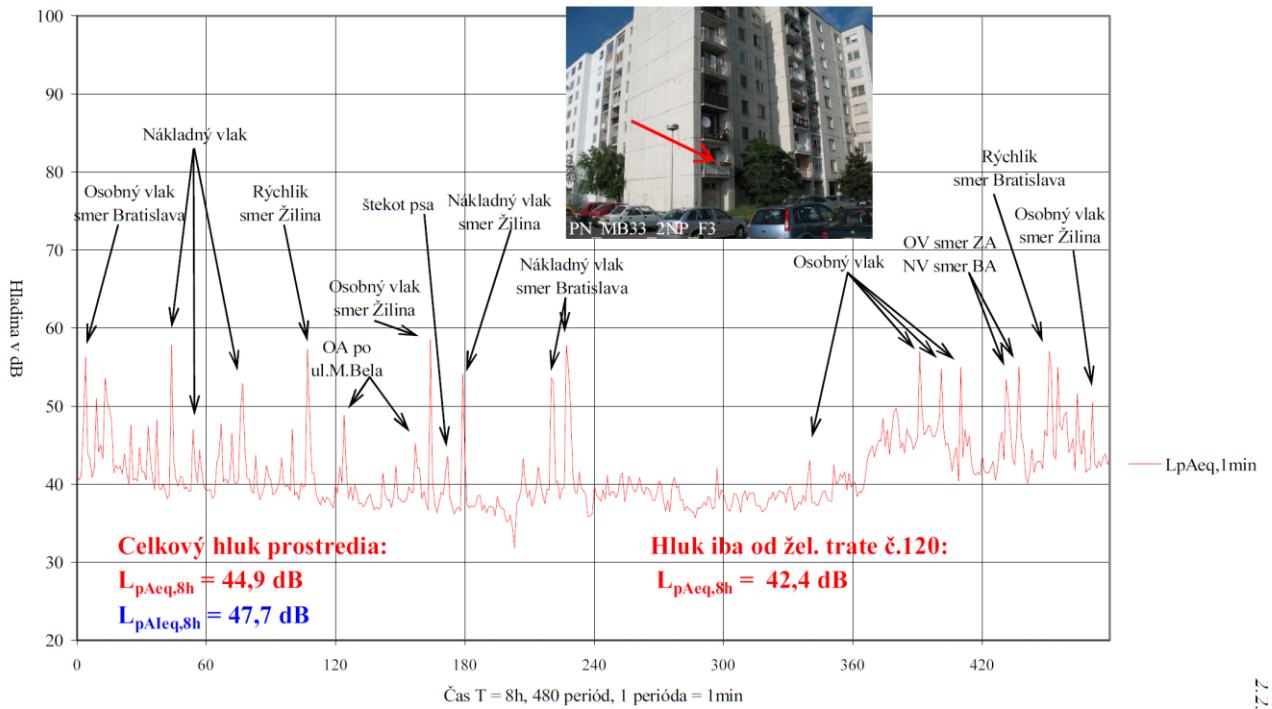


Fig. 16. Time diagram of equivalent noise pressure levels during 8-hour measurement in the measurement point M1

Rys. 16. Wykres hałasu podczas 8-godzinnego pomiaru w punkcie M1

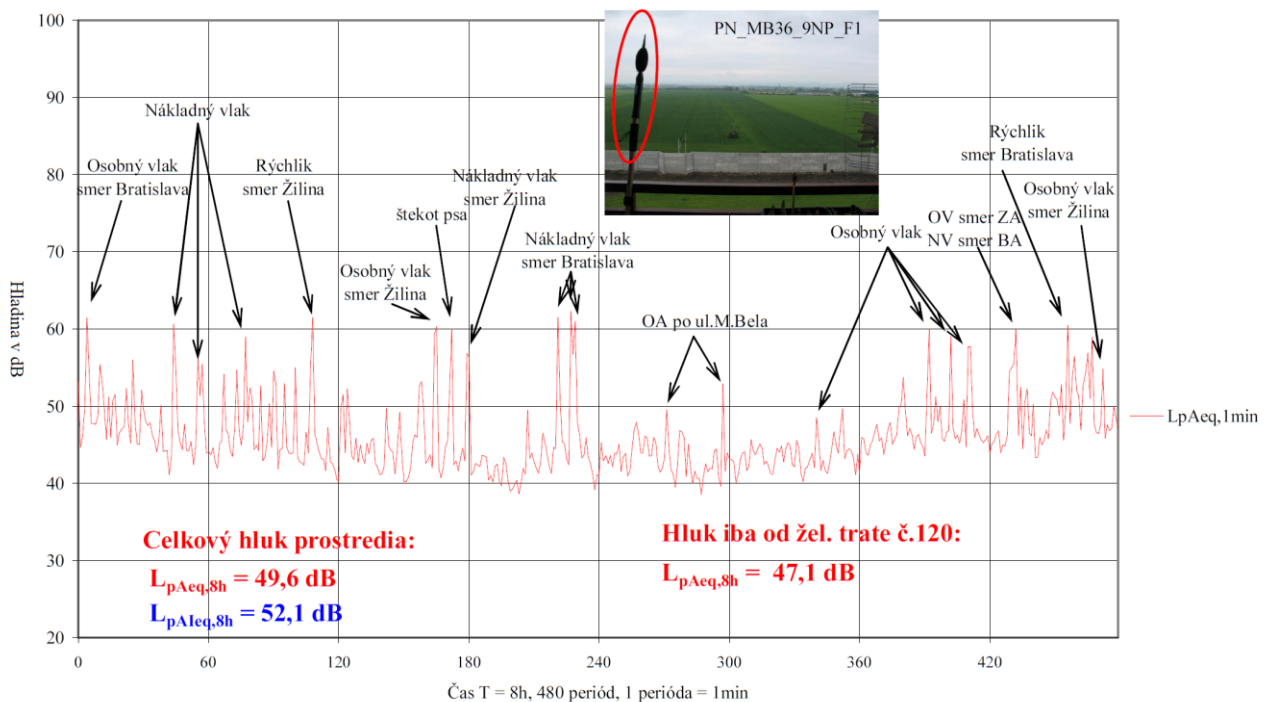


Fig. 17. Time diagram of equivalent noise pressure level during 8-hour measurement in the measurement point M2

Rys. 17. Wykres hałasu podczas 8-godzinnego pomiaru w punkcie M2

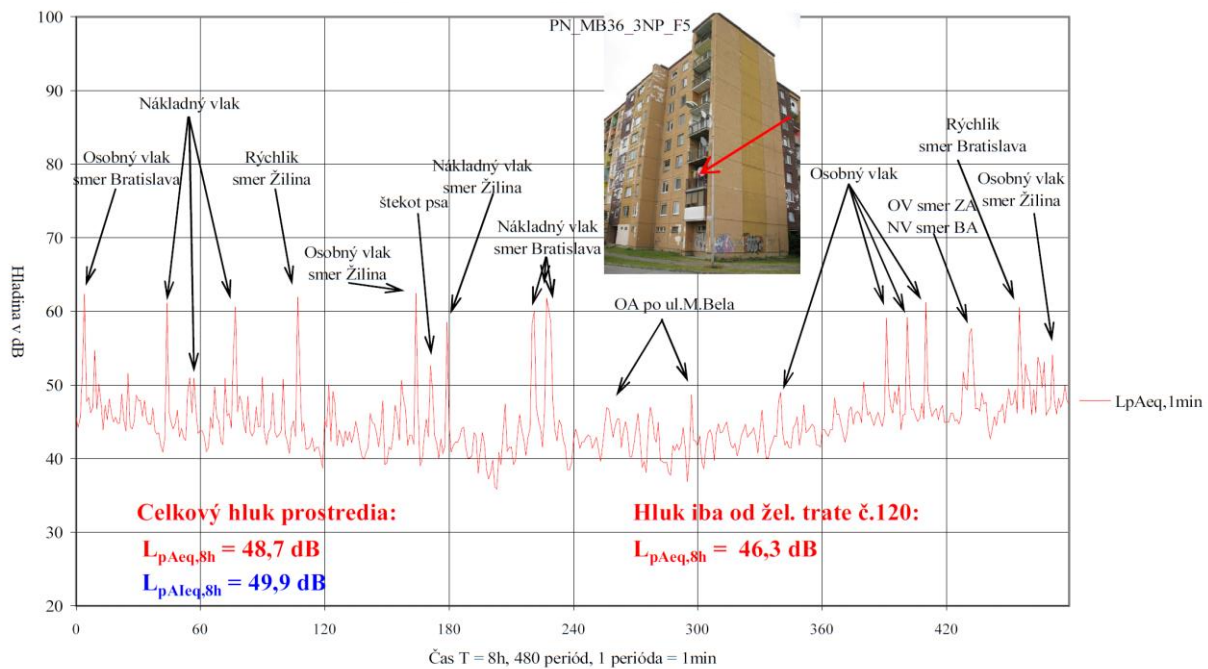


Fig. 18. Time diagram of equivalent noise pressure levels during 8-hour measurement in the measurement point M3

Rys. 18. Wykres hałasu podczas 8-godzinnego pomiaru w punkcie M3

The noise pressure level values $L_{Aeq,1h}$ (dB) in one hour obtained in the measurement points (M1, M2 and M3) are presented in Table 1 to Table 3.

Table 1

Equivalent noise pressure level values A in one hour measured in the measurement point M1

Time (hour)	22-23	23-00	00-01	01-02	02-03	03-04	04-05	05-06
$L_{Aeq,1h}$ (dB)	46.4	44.3	44.0	44.8	38.9	38.8	47.1	47.6

Equivalent noise pressure level A measured in the night period 22:00 - 06:00:

$L_{Aeq,8h\ night} = 44.9\ dB$... global noise – surrounding noise,

$L_{Aeq\ 8h\ night} = 42.4\ dB$... noise from the railway track no. 120.

Table 2

Equivalent noise pressure level values A in one hour measured in the measurement point M2

Time (hour)	22-23	23-00	00-01	01-02	02-03	03-04	04-05	05-06
$L_{Aeq,1h}$ (dB)	51.2	50.0	49.8	50.4	44.3	44.0	49.9	51.8

Equivalent noise pressure level A measured in the night period 22:00 - 06:00:

$L_{Aeq,8h\ night} = 49.6\ dB$... global noise – surrounding noise.

$L_{Aeq\ 8h\ night} = 47.1\ dB$... noise from the railway track no. 120.

Table 3

Equivalent noise pressure level values A in one hour measured in the measurement point M3

Time (hour)	22-23	23-00	00-01	01-02	02-03	03-04	04-05	05-06
$L_{Aeq,1h}$ (dB)	49.9	49.2	48.5	50.0	43.1	43.5	49.6	50.3

Equivalent noise pressure level A measured in the night period 22:00 - 06:00:

$L_{Aeq,8h\ night} = 48.7\text{dB}$... global noise – surrounding noise,

$L_{Aeq\ 8h\ night} = 46.3\ \text{dB}$... noise from the railway track no. 120.

4. RAILWAY NOISE MAP OF CHOSEN TERRITORY

The noise maps are created by software programs that contain certain calculation methods, which try to determine the noise level values from the source as exactly as possible, depending on the cartographic data, the character of built-up area, possibly already realised noise abatement arrangements. The most frequently used software programs in the Slovak Republic are: *HLUK +*, *CADNA*, *SoundPLAN*, *MITHRA*, *PREDICTOR*.

The following analytic noise map of the equivalent noise pressure levels A was worked out at these conditions:

- the measurements started at the time of the beginning of the railway emissions after the modernisation of the railway no. 120 with the noise barrier in the railway kilometre 81.500 – 82.300;
- the measurements were done at the height of 4.5 m above the surface;
- the measurements were done in the exterior area of A. Trajan suburb in the town of Piešťany, during the night time from 22:00 h. - 06:00 h,
- it was designed by the Cadna software with the application of the prediction model Schall 03. (Fig. 19).

The assessment of the noise map concludes that the limit value in the concerned territory is exceeded to **15.4%** of the considered area.

The noise assessment is carried out by the comparison of the assessed adjusted value of the equivalent noise pressure level A $L_{R,Aeq}$ with the limit values (*LV*) according the regulation [1]. For all the measured and calculated values the assessed value is increased by about $1.8\ \text{dB}$, which is the measurement uncertainty.

The values introduced in the Table 4 demonstrate, that the assessed measured values of the noise level $L_{R,Aeq,8h}$ are lower in all the measurements points compared to the limit values. The adjusted calculated value of the noise level $L_{r,Aeq,8h}$ is higher than limit value but the exceeding is small (Tab.4).



Fig. 19. Graphic output for the compliance assessment of the limit values of the noise levels in the exterior area of the town Piešťany territory in the time period 22:00-06:00 [12]

Rys. 19. Graficzna ocena poziomu hałasu w okresie 22:00-06:00 w mieście Pieszczyany [12]

In the case of the rail absorber application and the consideration of the declared reduction of the noise source by **5 dB**, it is possible to simulate the reduction of noise levels in the area of the modernised railway line using the software ArcGIS with the model ArcAkus and with the implementation of mathematical model of spreading the noise by Schall 03 methodology (Fig. 20).

Table 4

The comparison of adjusted values of the equivalent noise pressure level A $L_{RAeq,8h}$ measured in situ in front of the façade of the block of flats and calculated values $L_{r,Aeq,n}$ with the limit values for the given area

Assessment point (altitude from the ground/ distance from the rail track)	Land category	LV (dB)	Measured values (dB)	Assessment of adjusted measured value $L_{R,Aeq,n}$ (dB)	Calculated value (dB)	Assessment of adjusted calculated value $L_{r,Aeq,n}$ (dB)	$L_{r,Aeq,n}$, calculated - $L_{R,Aeq,n}$, measured (dB)
M1 4.5m / 105m	II.	45	42.4	44.2 < 45	43.4	45.2 > 45	0.9
M2 25.5m / 80m	III.	55	47.1	48.9 < 55	46.7	48.5 < 55	-0.4
M3 7.5m / 80m	III.	55	46.3	48.1 < 55	46.5	48.3 < 55	0.2

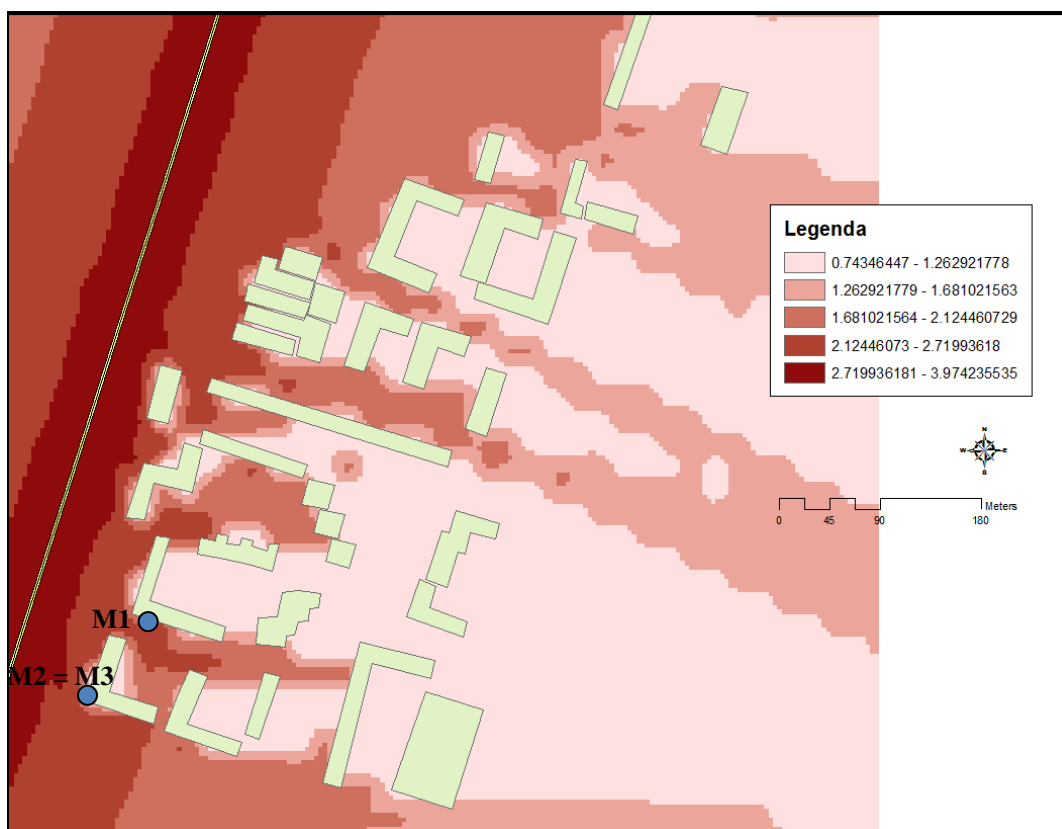


Fig. 20. Simulation of the noise emission reduction after installation of rail absorber systems
Rys. 20. Stymulacja redukcji hałasu przy zastosowaniu barier ochronnych

5. CONCLUSION

The Fig. 20 shows, that the correct application of rail absorbers caused the noise level reduction by about **1.3 dB** in M2 and M3 and consequently by about **2.0 dB** in the point M1, which satisfies the necessity of complying with the limit values for the noise imissions (Tab. 5). To summarize this, in the case of small values of exceeding the permissible noise imission values it is not necessary to build noise barriers, but it is enough to additionally reduce the noise level by applying the rail absorbers, which is not only more a economical, but also more aesthetic arrangement.

Table 5

The comparison of equivalent noise pressure level $L_{r,Aeq,n}$ after installation of the rail absorber with the limit values of the noise levels

Assessment point	Land category	LV (dB)	Assessment value $L_{r,Aeq,n}$ without rail absorber (dB)	Noise level reduction (dB)	Assessment value $L_{r,Aeq,n}$ with rail absorber (dB)
M1	II.	45	45.2 > 45	2,0	43.2 < 45
M2	III.	55	48.5 < 55	1,3	47.2 < 55
M3	III.	55	48.3 < 55	1,3	47.0 < 55

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