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APPLICATION OF LOW HEIGHT NOISE BARRIERS TO REDUCE RAILWAY NOISE

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Abstract. Railway noise is growing a global problem and the low height barrier may be the future for reducing noise from railways. Railroads are usually designed in cities, near buildings. Every day, in the European Union, some 12 million people are exposed to railway noise. Long term noise exposure can increase human health problems. At a lower level it may cause lower concentration at work, harder relaxation at home or even in the nature. In the worst cases, noise pollution may contribute to serious health issues including hearing damage, hypertension, headache and insomnia. Low height barriers may have high efficiency, but distance between source and barrier should always be the same. This type of barrier has a limited perspective of usage, one of the best situations – near railways. High barriers usually cover the view, and their installation has a large cost. But there are more disadvantages to high walls: they effect reflection sunlight, and frequently high barriers (which are 5 metres or more) may provoke claustrophobia in drivers while they are passing through. Low height barriers never cover the view, they have half the cost of installation, and may be constructed in a variety of shapes: such as Y, T, pearl, cylindrical, and arrows. The use of low-height barriers involves 50% less investment than high barriers. Low-height barriers effectively contain noise levels, with an effectiveness of 4 dB for a 1-metre barrier and 8 dB for a 2-metres barrier.

Keywords: railways noise barrier low height modelling.

Introduction

Railway traffic has many issues, but one of the main is noise. Noise is identified as one of the greatest challenges in the European railway system. Noise abatement measures must be taken to reduce as much rail transport noise as possible (Cheron et al., 2012). Noise has a negative impact on human comfort, so noise barriers are one of the best solutions to the problem today.

Noise – any unwanted sound, may occur unexpectedly, or be too loud or repetitive. At certain decibels, it can be hazardous to health, with low frequency noise as damaging as loud noise. Exposure to prolonged or excessive noise can cause a range of health problems. In 2018 the World Health Organisation (WHO) released a report, which highlighted serious health problems caused by environmental noise in western Europe. More than 100 million people are exposed long-term environmental noise and about 1.6 million heathy years are lost. Noise has many sources. The major cause of noise pollution are roads, but others, like railways have a significant contribution. The railways have the highest instantaneous noise waves, these lead to more complicated noise reduction. The total number of people with night traffic noise levels of 55 dB or higher is estimated to be 22 million for railway noise. (European Environmental Agency, 2019).

Noise pollution has solutions. It could be soundscaping, active noise controls utilizing various types of barriers. Barriers can be different by size, geometry, materials, and it could be absorption and isolations barrier types. The most widely used barrier is typical 3–5 m high and that usually has the highest efficiency on noise reduction. But low height barriers are highly efficient when matched to geometry and absorption. The low-height barrier has superiority against typical high barriers (Figure 1). The typical height barriers require high investment, usually cover the view, and create a shadow zone.

Railroads usually are designed in the cities near buildings. Every day some 12 million people in the European

Figure 1. Low-height noise barrier (Sound Im, 2019)

Union are exposed to railway noise. Long term noise exposure can increase human health problems. At low levels this may impact on concentration at work, relaxation at home or outside. In the worst cases, people may experience health issues such as hearing damage, hypertension, headache, insomnia, or other symptoms. It is important to note that noise pollution levels are affected by the tightness of windows, the construction and protection of buildings, greenery, the landscape, and the construction of the site (Lee et al., 2014).

Railway noise is a growing global problem and alternative the low height barrier might be future for reducing noise from railways, but there is not much scientific research of low height barriers and their application near railways.

The most common height of barriers is between 2–5 metres. The height of a barrier has a large impact on noise isolation and usually has high noise absorption efficiency. Barriers with these dimensions have the possibility to "catch" noise waves from various distances of source. Thus, barriers, if designed correctly, may isolate noise from cars which have variable trajectories.

Typical high barriers have an inclined cap shape. That shape has the highest possibility to isolate and absorb noise waves.

Low height barriers also could have high efficiency, but distance between the source and barrier always should be the same. This type of barrier has limited perspective of use, one of the best situations – near railways. In that case, trains never change their moving trajectories.

Low height barriers have some superiority over high barriers. High barriers usually cover the view, and their installation have a large cost. But there are more disadvantages with high walls: they have an effect on sun reflection from the barrier and often very high barriers (which are 6 metres or more) provoke claustrophobic emotions in drivers when they are driving between those barriers.

Almost all acoustic wall systems are fabricated on-site, i.e. H. All acoustic wall components (except foundations) are manufactured at the factory, then shipped to the construction site and assembled into a system. Here are some common types of noise barriers and their components: Y, T, pearl, cylindrical, arrow shapes

The following devices can be composed of acoustic and structural elements: Acoustic elements are elements whose primary function is to provide sound insulation, diffraction and/or sound absorption. A structural element is an element whose main function is to support or support an acoustic element, which is part of a noise reduction device used in transport infrastructure. They may consist of different materials, which are applicable to special standards according to the specifications. This European Standard specifies the relevant characteristics of rail traffic noise reduction devices, relevant assessment methods and provisions for conformity and production assessment. Where necessary, products covered by this standard shall be tested against the validation criteria. Test methods or calculation methods mentioned in the standard only allow the stated results, so the applicability standard is irrelevant.

Noise reduction measures in road traffic must meet the requirements of this standard and, according to the manufacturer, include:

- Product type identification;
- Factory production control, including product evaluation.

Methodology

This test uses a Bruel & Kjaer 2270 Precision Sound Level Meter Analyzer, which has two measurement channels, allowing simultaneous measurement of noise from both microphones placed in different positions. Thanks to the built-in processor and dedicated applications, the device can perform statistical processing of the measurement results. Noise data from Bruel & Kjaer 2270 was processed using Evaluator Type 7820 software for reporting. The functions of the software are:

- 1 or 1/3 octave range real-time analysis;
- Use preset labels to draw noise properties;
- recording;
- Broadband statistics;
- Data transfer (Venckus, 2011).

In addition, noise data must be measured during the day, evening and night. Daily sound level L_{day}. Equivalent continuous sound pressure level when the reference time interval is days. A day is between 7am and 7pm. Evening sound level $L_{day,h}$. The reference interval is the equivalent continuous sound pressure level in the evening.

Community Tolerance Level L_{ct}, the diurnal noise level at which 50% of people in a given community are expected to be significantly annoyed by noise exposure. L_{ct} was used as a parameter to explain differences between sources and/or communities when predicting the percentage of highly annoying noise exposure, short-term measurements.

The measurement interval was chosen so that any significant fluctuations in the noise emission are covered. If the noise is periodic, the measurement time interval should preferably comprise an integer number of periods. If continuous measurements cannot be made over such a time, the measurement intervals should be chosen so that they each represent a part of the cycle, and together they represent the entire cycle. Representative measurements can extend their representative time period and combine to form new results.

For short-term measurements of favourable conditions that require propagation over distances not covered by the equation, the minimum averaging time to average actual meteorological conditions is 10 minutes. However, longer times may be required to achieve adequate averaging of source conditions.

Position of the microphone. Selection of measurement points. The location of the measurement microphone should be chosen to minimize the effect of residual noise from unrelated noise sources. Microphone location selection, to assess the situation at a specific location, use the microphone at that specific location. In some special cases, the above locations are subject to further restrictions. For general surveying, use microphones with a height of (4.0±0.2) m in multi-storey residential areas unless otherwise stated.

Equivalent continuous sound pressure level within the time interval T,$_{Leq}$,$_T$. For short-term averaging, measure in the frequency band for at least 30 minutes.

Sound exposure levels during time intervals T, LE, T. Minimum number of events to measure source operations. Measure each event long enough to include all significant noise contributors. Differentiate between different vehicle classes

Excess level of N percentage during time interval T, $L_{N,T}$. During the measurement interval, briefly record $L_{eq,t}$ at least once per second.

Sound pressure level for which the sampling time is less than the time-weighted time constant used.

The class interval in which the recorded results are placed must be 1.0 dB or less. The parameter basis and time weighting (if applicable), recording period and class interval used to determine $L_{N,T}$ must be specified.

Maximum time-weighted sound pressure level, $L_{F,max}$, $L_{s,max}$. Measure the $L_{F,max}$ or $L_{s,max}$ of events for a given number of active sources, using the time-weighted F or S shown. Every result is to be recorded.

If the noise characteristics of the receiver site include audible tones, then an objective measure of the accentuation of the tones should be made. Select the loudest microphone position and continue the analysis.

Sound diffusion simulation program "CadnaA". There are several methods and criteria for evaluating noise:

- If it is known that an unplanned new noise source can be used, the sound pressure level of the existing noise source can be measured at selected points to assess whether the noise limit is exceeded;
- If a low-noise object is planned and there are no other objects nearby, a simple sound propagation calculation can be performed using the general noise reduction calculation method;
- If there is a planned object and it is known that it will generate a lot of noise, as well as residential environments and other noisy objects, it is recommended to use specialized noise simulation software.

The simplest way to assess environmental sound pollution is to measure the level of environmental noise sound pressure. However, the application range of this measurement method is quite narrow. There are many reasons why measurement methods cannot be applied or are economically unreasonable:

- The background environment noise level is close to the situation of the research source noise;
- Predict environmental noise levels before implementing environmental changes;
- When comparing alternative solutions to the problem of environmental noise reduction;
- Take measurements in hard-to-reach places.

When measuring noise from railway flows, the measurement was made under the same conditions (same noise measurement procedure, same instruments, same operator, same measurement location) and position if the changes have little effect on the results due to meteorological conditions.

When measuring L_{AeqT}, the number of passing trains were recorded. There are two types of trains: freight and passenger. 20 trains: 13 passenger and 7 freight were recorded.

The correction for the measurement conditions is calculated according to the formula (LST ISO 1996-2, 2017):

$$u_{sou} = \frac{C}{\sqrt{n}}, \tag{1}$$

where: u_{sou} – standard uncertainty; c – traffic index; n – number of passed trains.

For traffic index, c could be 10 (for the assessment of total train noise) and 5 (for the assessment of noise levels for individual types of trains (passenger, freight, etc.).

The sound pressure levels recorded depend on the meteorological conditions. The possible influence of meteorological conditions on the results of noise level measurements is estimated according to formula (LST ISO 1996-2, 2017):

$$\frac{h_s + h_r}{r} \geq 0.1, \tag{2}$$

where: h_s – height of the source; h_r – receiver height; r – is the distance between the noise source and the receiver.

Meteorological conditions were recorded during the measurement.

Noise levels were not measured when it was snowing, raining, foggy or when wind speeds were greater than 5 m/s. Therefore, before taking noise level measurements, a Testo 511 was used at a height of 1.5 m. The following meteorological indicators of environmental parameters were determined b the earth's surface: air temperature (°C), relative humidity (%), wind speed (m/s), barometric pressure (hPA), wind direction (°).

To model and predict the spread of noise, CadnaA (Computer Aided Noise Cancellation) software was used. It is software designed to calculate, express, evaluate and predict the level of noise and airborne sound pollution. The program is suitable in many cases – industrial plants, shops with car parks, streets, to assess railway or city-wide noise. The calculation results include the traffic flows generated at individual points noise level, local noise sources and exhaust gas concentrations are also assessed at various modelling points (Petraitis, 2010). The calculation results include the noise levels generated by railway transportation at different locations.

The software evaluates in detail the topography of the area, the concentration of locations, the sound quality of buildings, traffic flow, maximum speed, meteorological conditions, etc.

The program can evaluate and describe up to 16 million objects. Noise is rated according to EU directives.

For some special sources, such as road and rail transportation or airports, the acoustic emission volume is separated from the technical parameters.

CadnaA will record the noise level at any point and location on the horizontal or vertical plane or on the facade of the building. For some special sources, such as automobile and railway traffic and airports, acoustic emission is obtained according to technical parameters. Many national and international standards maybe chosen.

For modelling railway noise with CadnaA by data on modelling methodology and normative documents, the French national calculation methodology NMPB-Routes-96 (SETRA-CERTU-LCPCCSTB) may be used. This methodology recommends Directive 2002/49 / EC of the European Parliament and of the Commission of 25 June 2002 on the assessment and management of environmental noise and the Lithuanian hygiene standard HN 33: 2011. The noise impact assessment was carried out in accordance with the Law of the Republic of Lithuania Noise Management No. IX-2499 of 26 October 2004, which states that the noise limit value is average size.

In the CadnaA plan, the noise map is generated by specifying the noise source allocated locally. They may be at a specific height or absolute height. The noise map can be established by indicating the required steps (Baltrėnas et al., 2008).

Figures below (Figure 2–4) show the configuration of calculation which may be of a barrier, railway, receiver grid and grid appearance settings. These settings include all main inputs of modulation parameters: calculation method by standard, allocation hours, reflection surface and absorption coefficient.

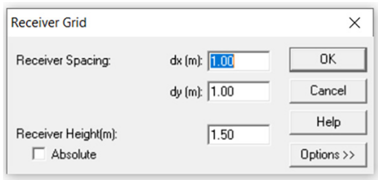

Figure 2. Receiver grid settings

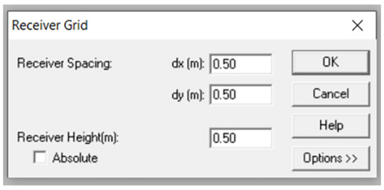

Figure 3. Vertical receiver grid

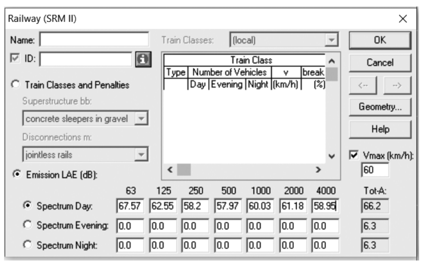

Figure 4. Railway noise settings

These parameters help to calculate the noise scatter of the program more accurately and with less error. The more the input parameter is known, the more accurate the modelling will be.

Models were set with correct parameters and I did not change any except those with a marked box, all emissions were at 0.5 above railhead and corrected allocation hours by Lithuania. Day, evening, and night hours set at 7-19, 19-22 and 22-07 hours respectively.

The ISO standard which CadnaA uses for calculation method. The main time stamp parameters were very important when comparing different day, evening, and night times.

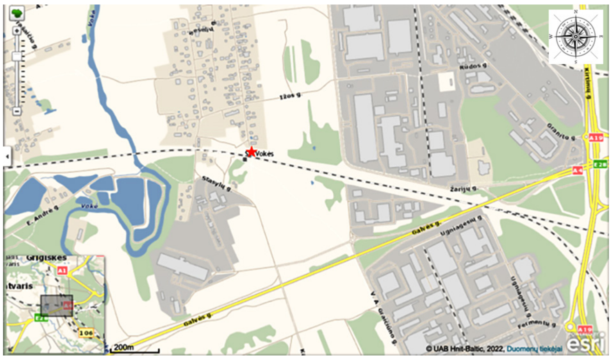

Figure 5. Investigation area marked measurement place

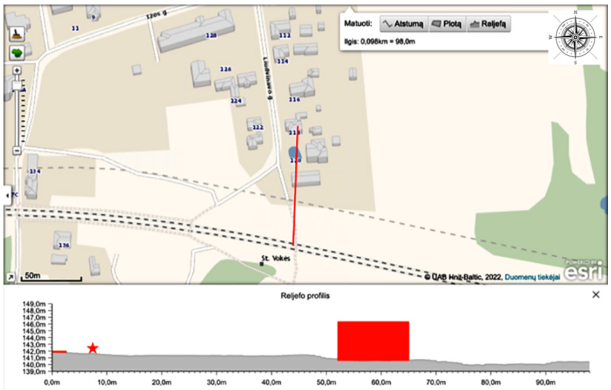

Figure 6. Investigation area with terrain profile of 100 metres

Investigation area was chosen near Vilnius city, at Liudvinavas. The measurement was performed on the 5th of December in 2021. In Figure 5 the red star is the exact location of the microphone. Figure 6 show terrain profile of 100 metres, chosen area are of very similar elevation.

The research location is an inhabited area which is not overgrown with trees or bushes. Measurements were taken at 7.5 metres from the railway.

Results

In this study, trains with recorded with radically different engines, and there was train stop near microphone

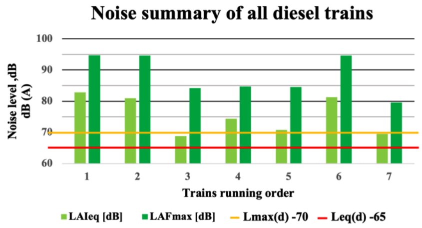

Figure 7. Noise of all diesel trains

location. In that case stopped trains noises were also measured. Before showing results, they were excluded, for example electric train noise, average L_{ALeq} is 71,46 dBA and exceeds 65 dBA.

Figure 7 shows the noise summary of all measured diesel trains. L_{ALeq} depicts actual noise level and L_{AFmax} depicts maximum recorded noise values. L_{ALeq} and L_{AFmax} exceeds corresponding values which are the main issue for people living nearby.

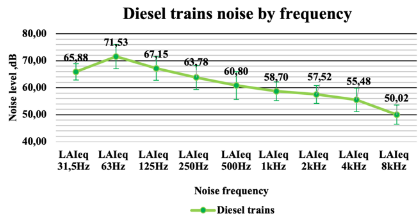

Figure 8. Investigation area marked measurement place

Figure 8 shows train noise by frequency and error bars. Diesel trains show a great variation. First, diesel values are high, but the lowest levels compare to electric trains, with a high frequency of 8k hertz. The diesel train chart shows a peak of 71,53 dB which is extremely high; for that level of noise, it is a priority to implement an economic barrier.

Evolving technologies give us many benefits, for example the development of the electric motor; all electric trains emit less noise. But they are much more expensive than diesel. So, most of the trains in Lithuania

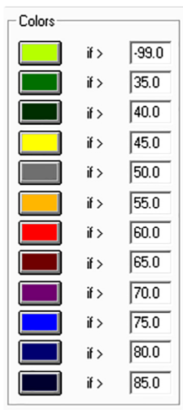

Figure 9. Grid scale

are already electric and all cargo trains have noisy diesel engines. The noisiest frequencies are between 31,5–125 Hz and exceed noise level from about 67–71 dBA.

Noise modelling from transport is a complex task and has many variations which may impact on a model's performance.

Figures 10 and 11 show noise spread at a village from trains. At different areas there are markers with noise level at differing distances from the source of the pollution and nearby housing, like the simulated value of noise between buildings is about 58.7 dB. Noise levels are indicated by Figure 9. Also near the railway is a receiver which is the same location as a mounted microphone and program which shows 71.4 dB noise level. From these figures it can also be seen that the noise threshold exceeded the value 65.1 dB near buildings without a barrier.

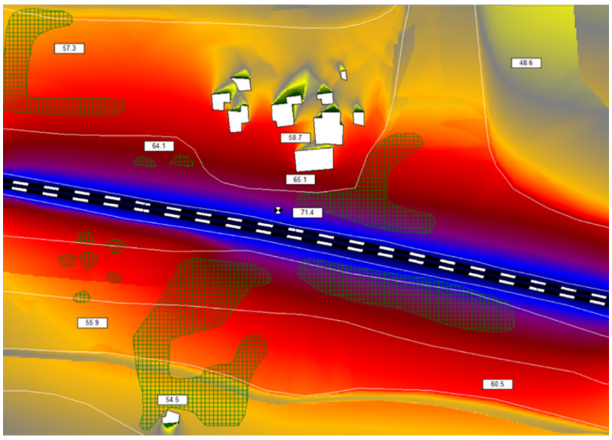

Figure 10. Modelled investigation area

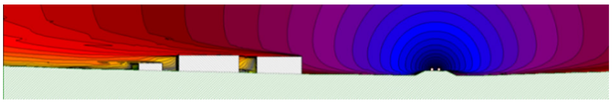

Figure 11. Modelled cut with linear spread

Figures 12 and 13 show that a 1-metre barrier has sufficient effectiveness in reducing noise by 3–4 dB, below

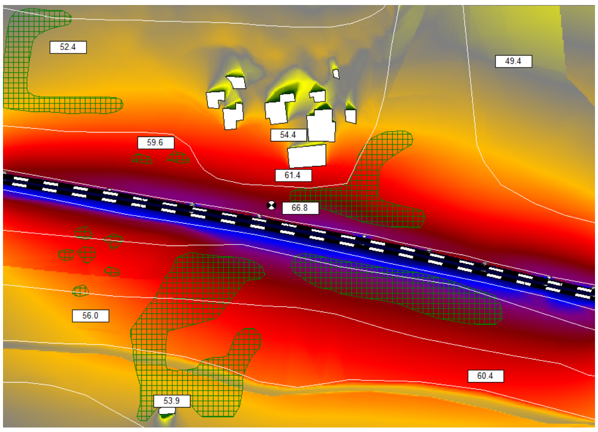

Figure 12. Modelled investigation area with 1 metre barrier

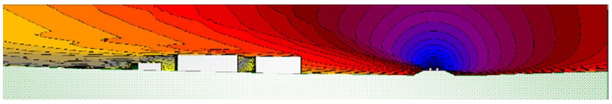

Figure 13. Modelled cut with linear spread with 1 metre barrier

the limit of 65 dB. Because noise levels near building are around 61.4 dB and the position between buildings shows a noise level around 54.4 dB. At the microphone location, the simulated program shows 66.8 dB noise level. This confirms that low height barriers may be the future of barrier installation along railways.

Low height barriers can not only be 1-metre ultra-small barriers, but also intermediate barriers of 2-metres. The standard height of barriers is 3-metres or more.

Figures 14 and 15 show that a 2-metres heigh barrier has an even higher efficiency of about 8 dB. Noise level at the microphone position was 63.2 dB, between buildings was about 51 dB and near the building was about 58.5 dB.

But this high barrier is twice as expensive to install and increases the likelihood of its design standing out from the environment.

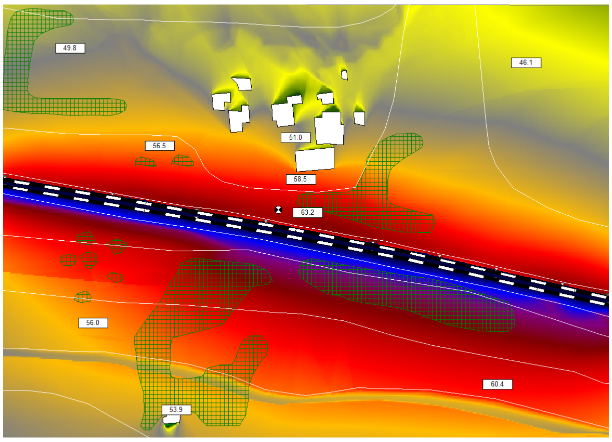

Figure 14. Modelled investigation area with 2-metres barrier

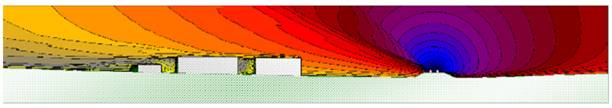

Figure 15. Modelled cut with linear spread with 2-metre barrier

One of the most informative model products is vertical grid cut. From Figure 15 noise spreads from the front. Over the buildings creates noise wave reflection and from this phenomenon noise shadows are formed.

The simulation program helped not only to capture the recorded noise values visually, but also to show how the wave propagates in the area and how it reacts when an obstacle is reached. No alpha coefficient was applied in the noise modelling, which indicates the object's noise absorption.

From the studies it can be concluded that low height barriers are an excellent alternative to large barriers and can have a high efficiency of up to 8 dB for a 2-metre barrier and the 1-metre barrier had a lower efficiency because its height limited the isolating waves, but it provided an important noise reduction in this situation and showed the full potential of small barriers.

Studies have shown that the barrier remains one of the most effective noise abatement measures and the introduction of low noise barriers is the future of noise abatement on railways.

In summary, a 1-metre barrier reduces noise pollution significantly below the threshold value by about 3 dB but does not eliminate physical noise. A 2-metress barrier has the potential to reduce the noise impact to a minimum noise level, with an efficiency of up to 8 dB, and these studies support the hypothesis that small noise barriers can be used for noise reduction.

Conclusion

1. A small noise barrier of 1-metre reduced noise levels from railways by 3–4 dB. This is not a large number, but it is enough to be perceptible. This type of barrier will not be very visible and will be inexpensive to install when compared to standard barriers.
2. The 2 metres noise barrier has been particularly effective in reducing the noise dispersion of about 8 dB. This is a high figure, but the barrier will be considerably more expensive than a 1 metre barrier and will be noticeable to residents.
3. The 1 and 2 metres heigh barriers confirm the hypothesis that they can be effective in reducing noise from railways, requiring at least half the investment and, most importantly, they are less visually damaging to the landscape than a typical 5 metres barrier.

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NEDIDELIO AUKŠČIO TRIUKŠMO BARJERŲ NAUDOJIMAS GELEŽINKELIO KELIAMAM TRIUKŠMUI MAŽINTI

D. Sarpalius, R. Grubliauskas

Santrauka

Šiuo metu geležinkelių keliamas triukšmas tampa pasauline problema, todėl ateityje geležinkelių keliamam triukšmui mažinti gali būti įrengiami alternatyvūs mažo aukščio barjerai. Geležinkeliai paprastai projektuojami miestuose šalia pastatų. Kiekvieną dieną tik Europos Sąjungoje geležinkelių triukšmas veikia apie 12 mln. žmonių. Ilgalaikis triukšmo poveikis gali pagilinti žmonių sveikatos problemas. Geriausiu atveju jis gali sumažinti koncentraciją darbe, apsunkinti poilsį namuose ar net gamtoje. Blogiausiais atvejais žmonės gali patirti didelių sveikatos problemų, tokių kaip klausos pažeidimai, hipertenzija, galvos skausmas, nemiga, taip pat yra ir daugiau ligų, kurias gali sukelti triukšmas. Nedidelio aukščio barjerai gali būti labai veiksmingi, tačiau atstumas tarp triukšmo šaltinio ir barjero visada turi būti toks pat. Šio tipo barjerų naudojimo perspektyva ribota, viena iš geriausių situacijų – šalia geležinkelių. Aukšti barjerai paprastai uždengia vaizdą, o jų įrengimas brangiai kainuoja. Tačiau yra ir daugiau aukštų barjerų trūkumų: jie turi tam tikrą poveikį saulės atspindžiui nuo užtvaros ir dažnai labai aukštos užtvaros (t. y. apie 6 m ir daugiau) sukelia vairuotojams klaustrofobinių emocijų, kai jie važiuoja tarp šių barjerų. Mažo aukščio barjerai niekada neužstoja vaizdo, jų įrengimo kaina perpus mažesnė, be to, jie gali būti įvairių formų: pasvirę Y, T, perlo, cilindro, rodyklės formos. Įrengus mažo aukščio barjerą, galima sumažinti geležinkelio triukšmo sklaidą į aplinką. Mažo aukščio barjerai veiksmingai sulaiko triukšmo lygį: 1 m barjero efektyvumas – 3 dB, 2 m barjero – 8 dB.

Reikšminiai žodžiai: geležinkeliai, triukšmas, barjeras, mažo aukščio barjeras, modeliavimas.