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EFFICIENCY OF ANTI-NOISE BARRIERS IN RAILWAY TRANSPORT

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Abstract: This paper is focused on the comprehensive analysis of the railway noise issues. It deals with the influence of noise on the environment and presents the options how the noise from the railway transport might be reduced by noise barriers. In conclusion, the theoretical part is complemented by a practical one in the form of measuring and subsequent analysis.

Keywords: absorbing, noise, railway transport, train, wall.

Introduction

The sound is one of the essential component of the environment and the world in which we live. It is a gradual longitudinal mechanical wave of the flexible medium which is perceived by hearing. It is created by oscillation of liquids, solids or air, either due to natural phenomena occurring in the environment or human activities. The human ear is able to detect the sound of frequency in a range from 20 to 20.000 Hz [1].

The term noise means any sound that is unwanted or has negative or unpleasant effect on our organism. There are many technical definitions of the noise but generally it is a sound that disturbs, harasses or harms the human (human health, property or the environment) [2].

Influence of noise on theenvironment

The negative effects of noise on humans can be divided into organ effects, activities interference (for example sleeping) or effects on subjective human emotions (harassment). Also, the noise may cause worsening of pre-existing diseases which have multifactorial causes [3].

Organ effects can be further divided into specific and nonspecific. Nonspecific affect multiple organs with influencing of their activities under stress or nerve irritation. Specific effects mean the malfunction of hearing and hearing organs. It can be caused by either one-time action of the extremely high noise level (about 130 or 140 dB, for children also lower), and thus damage the tympanic membrane, acicular or pellicular labyrinth [4].

The animals are the integral part of the environment. In recent decades we can also monitor the changes in their behavior caused by the increasing of noise from human activities. They could be directlyaffected on their physiological condition or they could have problems with mutual communication between individuals of the same species but they could also havesecondary problems indirectlycaused by noise, for example the construction of anti-noise measures.

There are animals for which excessive noise is detrimental, not conducive to their lives and they flee before it. However, there are some species of animals which seek excessive noise and they move to places with a higher incidence of noise (such as mice). There are also species of animals which simply habituate to noise (such noise at the construction of new railway lines). There are some cases where a badger or fox raised young ones in a hole duged in the railway embankment. However the migrating animals are not able to adapt to excessive noise due to the periodic change in the environment [5].

A major problem may be a violation of natural communication between animals, the researchers of the Institute of Biology in Leiden in the Netherlands give a specific example. They studied the great tit living in the Danish forests and found out that the males sing with the voice of very low frequency, especially at the time when the females are most fertile. The males with the deepest voice are the most effective during courtship. In the urban environments, parks and surrounding areas, there is a proliferation of sounds with a lower frequency which disturb these songs–merging them with the background noise. The male must therefore sing with higher frequencies but that means that it will be less attractive for the female [6].

The secondary consequence of noise barriers building on the railway is a landscape fragmentation, that means a division of the natural routes of animal's movement. Some species of animals are able to overcome some extent of this fragmentation but the others not. The solution may be the elevated corridors allowing the animals to get through with the communication (railways or road) without harm. A biocorridor is a territory which does not lend itself long-term existence of incriminating organisms but combines individual biocentre for networking. They are built mainly in the form of short tunnels under the track or on the track itself in the environment of the railways.

Another problem is numerous animal deaths in the places where noise barriers are built only on one side of the track. Animal that enters the track with the intention to continue, remains trapped and it may be knocked down by a passing train. This is a relatively common phenomenon.

Another problem may be reflective noise walls which are often made with transparent materials. So they do not interfere with the landscape and the views of the train passengers but they can be an obstacle for the birds. They do not see them and simply strike the wall. This problem is often solved by placing of the stickers with the dark outline of a bird of prey for deterrence [5].

Possibility of noise reduction in railway transport

Transport infrastructure is the most significant source of noise in many countries. Rail transport is generally considered among the modes of transport that are environmentally friendly. It is really true in comparison with other transport modes, especially in the area of production of GHG and other pollutants emitted into the atmosphere by vehicles. Beyond the occupation of the land noise is the component which causes the greatest problems with respect to the impact of railway on the environment. In order to address the noise reduction in railway traffic it is necessary to analyze its sources first [1].

Noise emissions from the railways cannot be generalized because they come from multiple sources whose intensity varies depending on the speed and design of the train, as well as on the surface of the railway permanent way. Multiple studies declare that at speeds of up to approx. 40-60 km/hnoise from sound of traction motor is the most important. From approx. 40-60 till approx. 160-200 km/h the noise of wheels rolling dominates and the higher speeds the aerodynamic noise is dominant (Fig. 1). Among the less substantial but not negligible sources of noise there are noise of pantograph and local traffic noise [7].

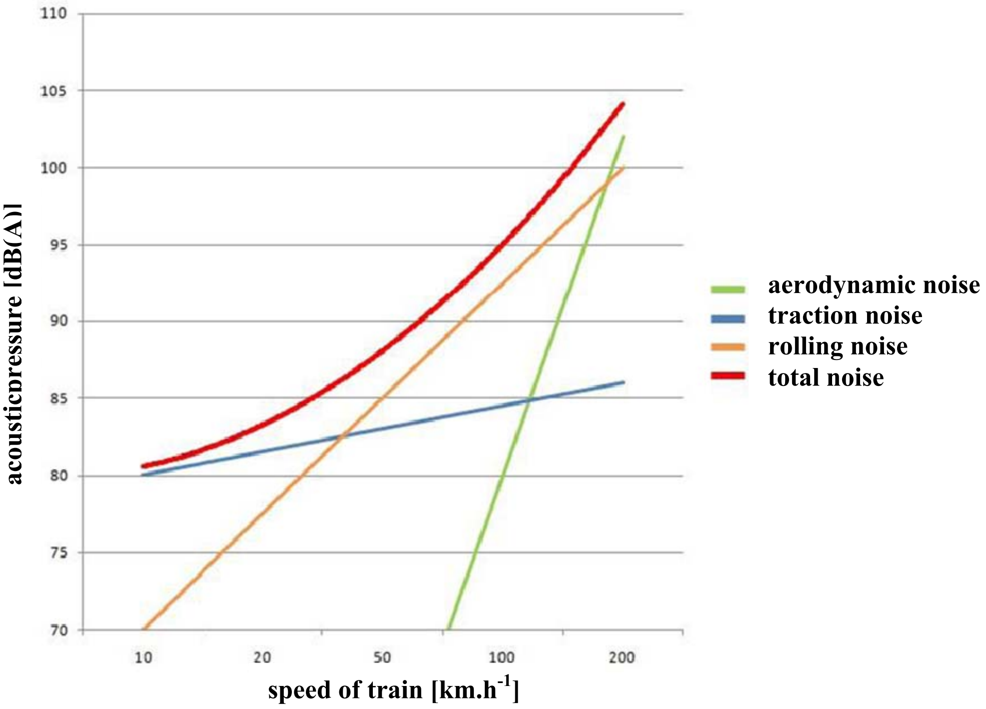

Fig. 1. The share of individual noise sources in the total [8].

The current weather situation also plays a significant role in the noise propagation from the railway traffic. This applies particularly to a distance of over 100 meters but the noise may also be absorbed in smaller distances by snow or sound reflections from different layers of the air. Generally, higher humidity also causes better propagation, so the noise can get even further than in the dry air. The wind has a significant impact on propagation as well. Its speed generally increases with height above the ground. Under normal conditions, the sound spreads radially from the noise source. If we consider the train as a source of noise at ground level, noise spreads not only laterally but also diagonally upwards (Fig. 2).

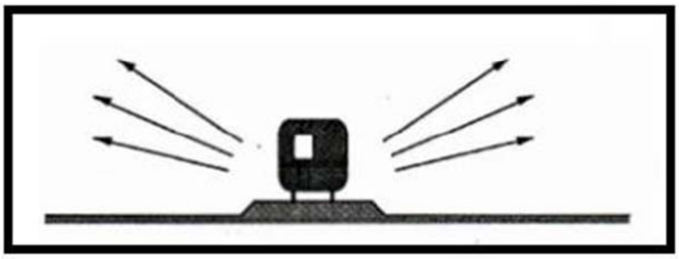

Fig. 2. Noise propagation in normal conditions [8].

Assuming that higher layers have higher wind speed thus wind tends to rotate noise rays going upwind upwards. Conversely, the sound on the other side of the train which has the same direction as the wind flow is dispensed towards the ground (Fig. 3). This may ultimately cause that at the same distance from the track on the windward side a measurable noise level may be substantially lower than on the leeward side of the track.

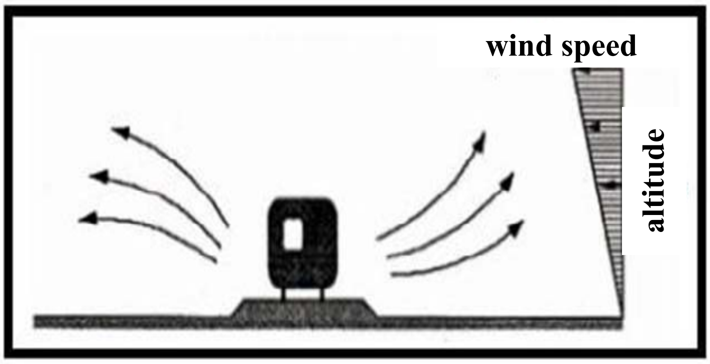

Fig. 3. Noise propagation with the wind [8].

Temperature gradient is another important factor. Under normal weather temperature decreases with increasing altitude. That causes bending of sound waves upwards. Inversion weather may occur especially in the winter time when the gradient is rotated and the ground temperature is lower. Then the direction of sound propagation has tendency to rotate back to the surface (Fig. 4).

The wind speed and its direction can significantly affect the propagation of sound and its value in individual locations. Therefore, the studies about traffic noise at specific sites have to deliberate not only current meteorological situation but it is also necessary to take into account the long-term condition, including regular rainfall and wind gusts [8, 9].

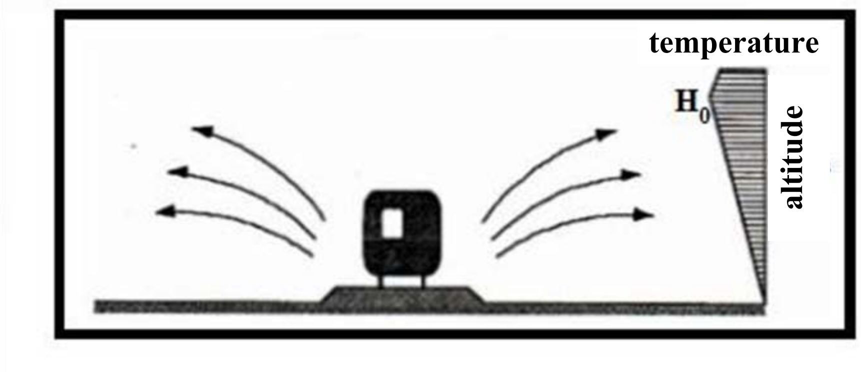

Fig. 4. Noise propagation with inversion weather [8].

Passive noise reduction measures

These measures do not regulate noise sources in any way but they reduce negative consequences of existing of unwanted sounds. The noise barriers are typical examples, especially noise walls, soil mounds and other obstacles. The history of noise walls building dates back to the 20s of the last century when the first specimens were built in the USA to protect people from the effects of road transport.

In the beginning, the emphasis was mainly placed on their function, mostly monolithic walls with smooth surfaces were used and walls often did not fit into the surrounding environment. Only later aesthetic demands were increased and walls started to have more fragmented shapes. At present, these elements count as an essential part of rail corridors constructions, they also often have artistic value and aesthetic appearance [8]. This measures, however, do not involve only positive facts in the form of reduction in noise pollution but also many negatives, for example large land occupation or problems with the intervention of the integrated rescue systems.

Noise barriers can be divided into reflecting with the smooth surface (Fig. 5) or absorbing with the rugged folds made not only on the reflection of sound waves but also on their direct restriction (figure 6). Reactive walls containing cavities or resonators are included in the special categories [10].

Fig. 5. Reflective surface noise barrier [13].

Fig. 6. The surface of the absorbent noise barrier [13].

Wide green belts can be another measure in the environment of the railway tracks. They can be combined with soil mounds. Their advantage is the fact that they do not only capture the noise but also the dust and they also often have a higher aesthetic level and make the environment nearby noise sources more cultural. The most significant disadvantage is that in the winter time, when deciduous trees are without leaves, the effectiveness of this measure is much reduced [1].

Analysis of efficacy of anti-noise measures

Here we have analyzed and compared the values of acoustic pressures generated during the passage of trains without the use of anti-noise measures and with using of the most common technical noise protection measures on the railways which are the absorbing noise barriers. A sound meter with accessory and audio filter A (human ears) was used for the analysis. Before measuring the sound level meter has been calibrated. Three measurements of approx. five hours were performed on the final. The locations were chosen where it was possible to measure half the time with noise barrier and another half time without noise barrier. Measurements were performed in the direct proximity to the railway tracks (up to 20 meters). A stepping frequency of one hertz was used, therefore, sound meter recorded the sound pressure level in the memory every second. The maximum values were used for analysis. The measurements were processed in accordance with the Guidelines for calculating the levels of traffic noise from Research Institute of Construction and Architecture of Prague, town planning office in Brno, as well as with other literature [11, 12].

First measurement

For the first measurement, a location on the border between the station gridiron and the railway station Ostrava-Svinov in direction Hranice (261st kilometer of the railway line SŽDC number 270) was chosen. The area on the main track was deliberately chosen, first due to the high frequency of trains and second because of the fact that this was the area with the number of different types of trains. Specific locations then met the requirements for the presence of absorptive noise wall and places without it. The majority of trains stop in this station, so we analyzed the noise especially during starting and braking of the trains.

The measurements were taken on 18th of March 2016 from 12:10 p.m. to 01:55 p.m. The temperature was 10°C and humidity 45%. The values of noise are shown in tables 1 and 2, graphically in Fig. 7 and 8. For each measurement, type of train was remarked.

Average values of the noise for each type of train are shown in Fig. 9.

Tab. 1. Relevant measured values from the first measurement behind the wall.

Time of measurement [min.]	13	16	21	26	26.5	33	36	43
Acoustic pressure [dB(A)]	67.2	69.3	69.3	65.9	60	65	68.2	71

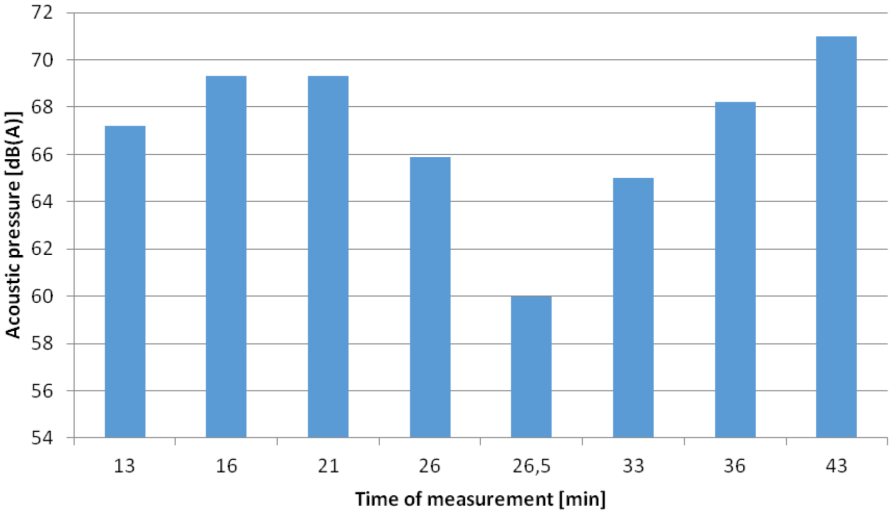

Fig. 7. Relevant measured values from the first measurement behind the wall.

Tab. 2. Relevant measured values from the first measurement without the wall.

Time of measurement [min.]	3	3,5	9	14	15	17	20	21	24
Acoustic pressure [dB(A)]	83.1	97	67.4	78.7	89.9	75.6	68	78.4	61.2
Time of measurement [min.]	31	35	38	41	42	45	49	50	
Acoustic pressure [dB(A)]	78.4	67.1	68.7	75.7	90.5	72.8	85.4	79.1	

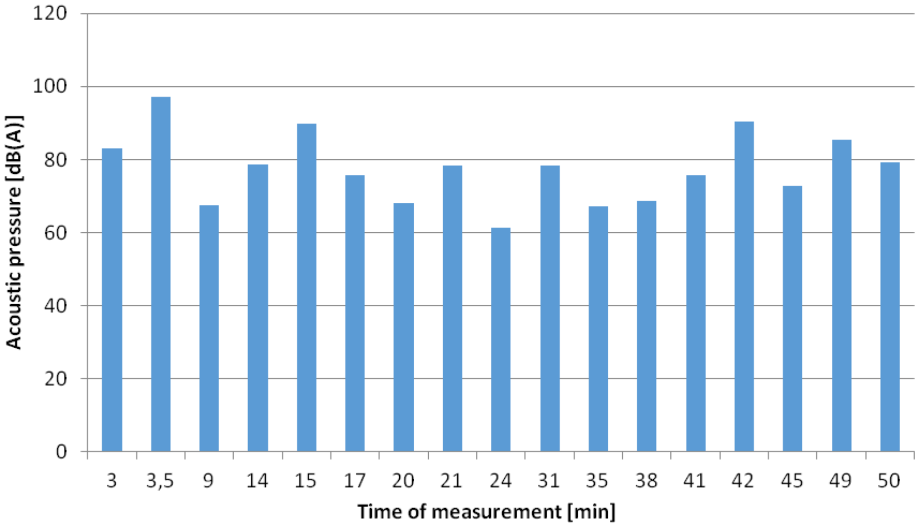

Fig. 8. Relevant measured values from the first measurement without the wall.

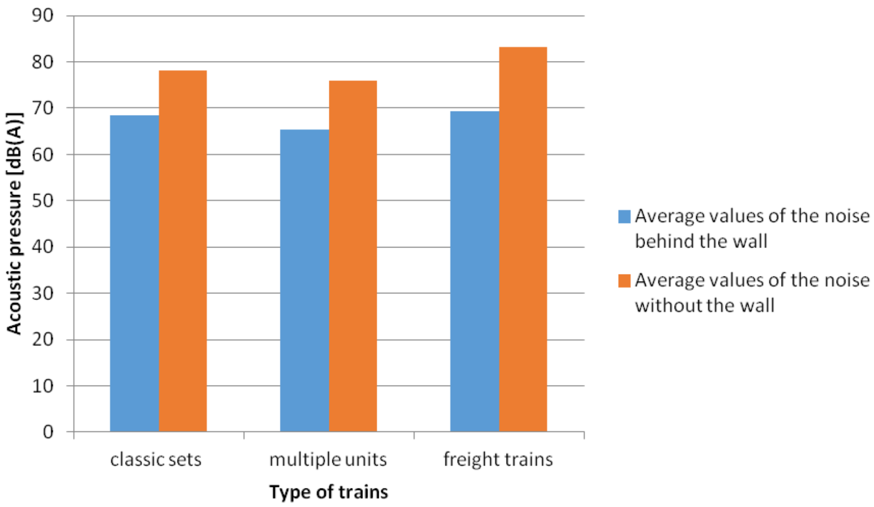

Fig. 9. Average values of the noise for each type of train from the first measurement.

Finally, the degree of noise reduction was analyzed for different types of trains and also collectively for all trains. The average values are shown in the graphs in figure 10.

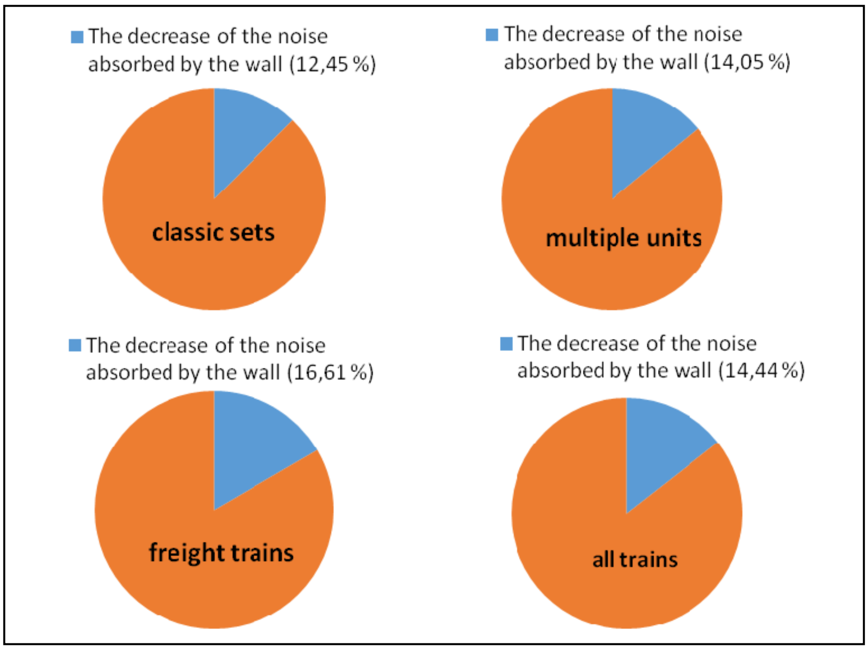

Fig. 10. The proportion of the noise absorption in the first-measurement.

Second measurement

The second measurement was done on 21st of March 2016 in the gridiron station Suchdol nad Odrou direction Ostrava (233rd kilometer of railway line SŽDC number 270). The place had a wider range of vehicles (in this station there were also coaches we could not measure in Svinov). Another advantage was that some types of trains (fast trains and passenger trains) stop on this station but others (EuroCity, SuperCity) pass it. It helped to make analysis of the noise from starting, braking and passing. The measurement was done from 2:03 p.m. to 4:05 p.m., the air temperature was 4°C, humidity approx. 50%. The maximum measured values of the noise are shown in tables 3 and 4 and graphically in figures 11, 12, 13 and 14.

Tab. 3. Relevant measured values from the second measurement behind the wall.

Time of measurement [min.]	5	10	12	15	28	30	31	37	49	52
Acoustic pressure [dB(A)]	76.5	73.2	71.2	65	71.2	67.7	57.1	71.2	68.7	57.1

Tab. 4. Relevant measured values from the second measurement without the wall.

Time of measurement [min.]	5	10	13	27	28	30
Acoustic pressure [dB(A)]	85.7	58.4	87.4	73.2	79.4	85.1
Time of measurement [min.]	34	45	49	49,5	54	58
Acoustic pressure [dB(A)]	81.2	81.8	73.8	85.9	80.4	73.4

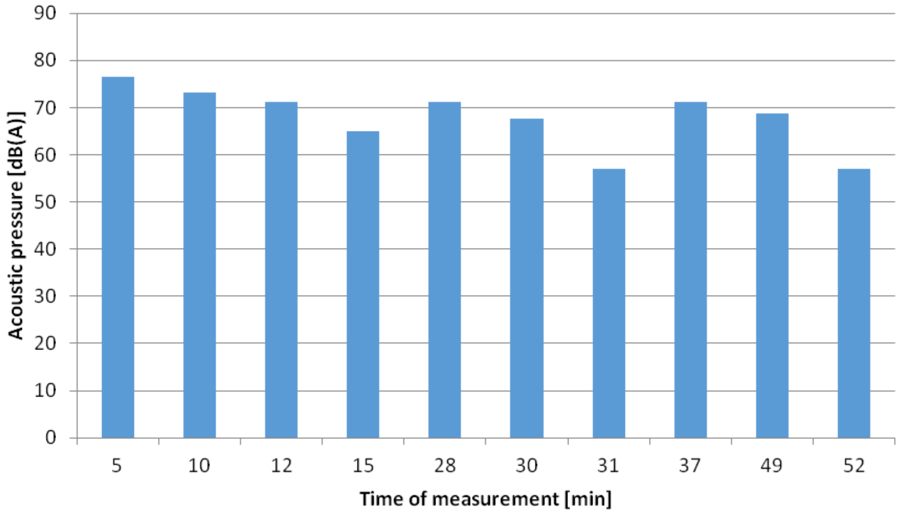

Fig. 11. Relevant measured values from the second measurement behind the wall.

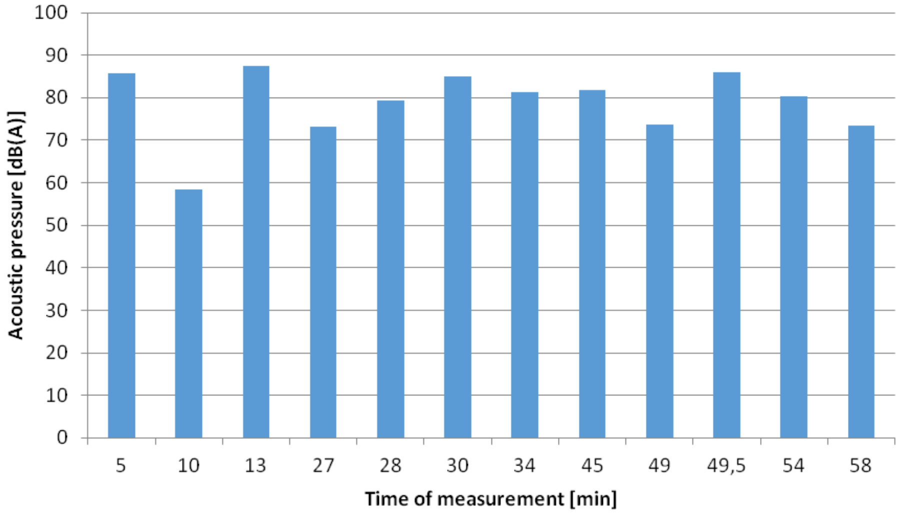

Fig. 12. Relevant measured values from the second measurement without the wall.

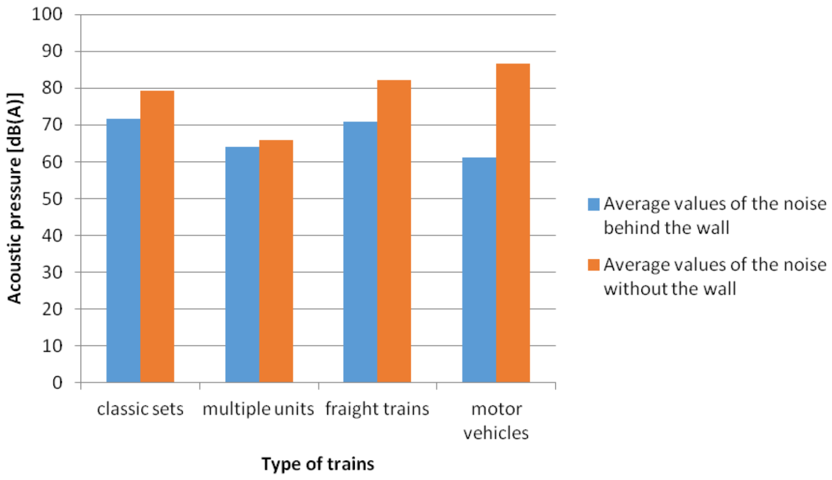

Fig. 13. Average values of the noise for each type of train from the second measurement.

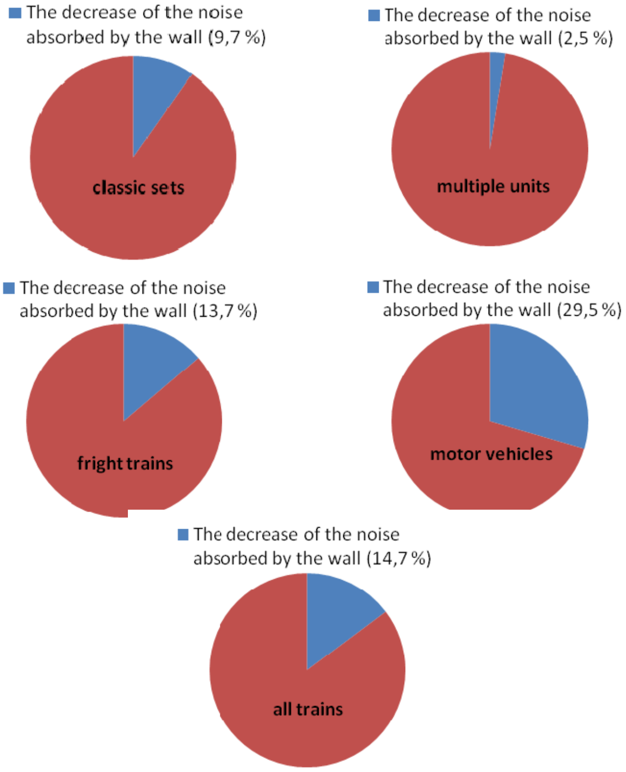

Fig. 14. The proportion of the noise absorption in the first-measurement.

Third measurement

The third measurement was done on 22nd of March 2016 in Zilina, the local part Brodno (4th kilometer of the track ZSR number 127). These measurements were the least successful for two reasons. First, the weather conditions changed in very short intervals and second, this track was not so often operated, so in a similar time period the number of values was very little to create statistics. The only relevant information from the measurements was that the average decrease of the noise absorbed by the wall was collectively comparable with previous measurements (about 14%).

Conclusions

The analysis showed that the noise barrier was most effective for the freight trains, at least for multiple units. In comparison with figures number 10 and 14, the freight trains appear the noisiest trains and multiple units the quietest ones. The logical conclusion can be easily deduced that the volume of the sound pressure which is a wall able to absorb is not absolute number but percentage and directly proportional to the size of the sound pressure of the incoming source. However, on average level these walls reduced the noise by more than a tenth. It may seem like a relatively small number but compared to the thresholds of noise causing lasting consequences on health it can be easily deduced that these walls can be critically helpful to human health. Moreover, it is also necessary to consider the fact that the decibel scale is logarithmic, so even a small decrease or increase in the measured sound pressure can result in abrupt mean difference in human perception. Most of the scientific literatures agree that anti-noise walls reduce noise from 5 to 15 dB (A). Figures 9 and 13 conclude that the measurements confirmed these theses.

The measurements confirmed the widely reported conclusions regarding anti-noise walls but also brought a number of (objective and subjective) findings. Taking into account all the factors we can recommend building of anti-noise walls as effective anti-noise measures for the areas immediately adjacent to the track.

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