Design and analysis of noise protection measures for a residential building near a railway line

Anastasia Opatskikh*

Rostov State Transport University, 344038 Rostov-on-Don, Russia

Abstract. The article presents a solution to the problem of determining the impact of noise level on a residential low-rise building near a railway line, based on initial data. Based on the initial data, the author found the analytical value of the existing sound pressure level by considering factors such as the number of train pairs and types of trains, speed, and distance to the axis of the outermost track to the object under study. The analysis focused on the existing measures employed for noise protection and reduction. The author suggested an optimal set of measures for this location. To assess the efficacy of the implemented solutions, the author devised a sequence of analyzes. The author provides the conclusion and analysis of the most effective and economically workable measures.

1 Introduction

Currently, a significant number of residential buildings in cities and rural settlements are within the railway line protection zone. A striking example is the buildings along the coastal line of the Black Sea coast, the Tuapse-Adler railway line. The construction of these buildings took place before the adoption of normative documentation that required considering the right-of-way and protection zone in the design of residential buildings.

The main hazardous and harmful factors affecting the health of people living in this zone is the noise impact from trains. Therefore, the analysis and subsequent development of such measures is a relevant topic of the research. The study was carried out on a site with the following characteristics: a low-rise residential building located 45 m from the track edge axis of a double-track railway line with an average capacity of 90 pairs of trains per day, a percentage of 50% freight and 50% passenger trains and speeds of 90 km/h and 70 km/h respectively, the track structure being a link track.

2 Theoretical concepts

Noise impacts have a negative impact on human health and life activity. The studies [1] demonstrate that noise not only affects our mental health but also has a direct impact on our

* Corresponding author: opatskih@yandex.ru

physical well-being, contributing to the development of cardiovascular diseases and ultimately reducing life expectancy. The article [2] states that in buildings densely next to railway lines, the noise level reaches over 75 dB. This level of noise shows a significant excess of permissible sanitary norms by several times [3].

Noise effects from the operation of the railway line are compounded. Their propagation speed, magnitude and frequency depend directly on the characteristics of the area where the facility is located. They depend on such characteristics as wind patterns, air humidity, existing terrain. Also, the technical characteristics of the railway track and rolling stock have a significant impact: the design of the upper and lower track structure, the percentage number of cars, the plan of the railway section, its longitudinal and transverse profile, the slope of the route, the technical condition of the track and rolling stock. On this basis, the railway track and rolling stock must be in good condition.

3 Research method

To assess the noise and select safety measures for a low-rise building near a railway track, perform the following calculation. By using the formula, we can calculate the sound pressure level (SPL):

$$SPL = L_p - 20 \cdot \log\left(\frac{r}{1m}\right), \tag{1}$$

Here, L_p is the value of the sound pressure level. Here, the source of noise impact is located one metre from the object under study, dBa; r - distance of the investigated building from the railway line, m.

According to [4] the value of sound pressure for passenger trains, which are at a distance of one metre from the object of study is 90 dBa, and freight trains - 100 dBa, respectively. Thus, we calculate SPL for the object under study according to formula (1):

- from passenger trains, dBa:

$$SPL_1 = 90 - 20 \cdot \log\left(\frac{45}{1}\right) = 56,94,$$

- from freight trains, dBa:

$$SPL_2 = 100 - 20 \cdot \log\left(\frac{45}{1}\right) = 66,94$$

Next, we calculate the sound flux (I) by applying the following expression:

$$I = \frac{P^2}{\left(4 \cdot \pi \cdot r^2\right)}, \text{ W/m2} \tag{2}$$

Where P is the sound pressure value, Pa; r - distance of the building under investigation to the railway, m.

According to the normative documentation [5], the value of the sound pressure level for passenger and freight trains from the railway corresponds to 0.002 Pa and 0.02 Pa sound pressure respectively (the distance of 45m between the train and the railway is taken). Then we calculate by formula (2):

- for passenger trains:

$$I_1 = \frac{0.002^2}{\left(4\cdot\pi\cdot 45^2\right)} = 1.57\cdot 10^{-9}$$

, W/m²;

- for freight trains:

$$I_2 = \frac{0.02^2}{\left(4\cdot\pi\cdot 45^2\right)} = 1.57\cdot 10^{-8}$$

, W/lines, to find the values of the equivalent sound pressure level we use the following expression:

$$L_{eq} = 10\cdot\log\left(\frac{I}{I_0}\right), \tag{3}$$

Here, I_0- value of threshold sound pressure, Pa;

- for passenger trains, dBa:

$$L_{eq1} = 10\cdot\log\left(\frac{1.57\cdot 10^{-9}}{10^{-12}}\right) = 76$$

- compounded freight trains, dBa:

$$L_{eq2} = 10\cdot\log\left(\frac{1.57\cdot 10^{-8}}{10^{-12}}\right) = 86$$

.

We can conclude that in this case, the noise level significantly exceeds the permissible values. We compare the average values of noise level from road traffic and from railway transport. Under these conditions, the values significantly exceed the norms.

Thus, for the values, we will consider protective measures combining their different types. Some of the protective measures aim to change the structure of the railway track, while others target the structure of the building. In addition, all the measures taken were optimal and economically workable.

Both the inside of the dwelling and the surrounding area are being analysed for sound levels. They are equal to 45 and 55 dBa respectively in terms of numerical value [6].

To reduce the noise level inside the residential building, we recommend using sound-absorbing panels on the façade. It is also necessary to use sound-absorbing materials for internal finishing. It is also necessary to install windows and doors with thickened double-glazed windows. This method is effective, cheap, but insufficient in these conditions. In order to achieve the required standard values, we will partially change the design of the railway track and the adjacent area.

There are the following measures to reduce noise from a railway line with changes in its design: replacing the link track with a sheetless track, reducing the speed of trains, using special linings on the rail neck, replacing locomotive brake pads with composite ones, and using sub-ballast mats.

It is possible to install noise screens, galleries between the railway and the residential building under consideration. Forest protection plantations are not relevant in this case because of the proximity of the object to the railway tracks.

According to the studies reviewed in [7-12] each of the above measures reduces the total noise level by a certain value. For example, the construction of a track without ties by 2 dBa, changing the type of pads to composite ones by 8 dBa, special overlays on rails - 5 dBa, the use of sub-ballast mats - 3 dBa, noise shields - 15 dBa, noise protection galleries - 25 dBa, noise protection panels of building facades - 10 dBa, thickened double-glazed windows - 10 dBa, reducing the speed of the train - 5 dBa.

We will assess various options to determine the best set of measures. Based on the above calculation, we conclude it is necessary to reduce the noise level by at least 41 dBa to the recommended normative level, since we focus on freight trains. Here, freight trains have a greater impact and a larger value.

We should remember that the selected measures should be cost-effective and should not surpass the cost of demolition and resettlement of the residential building.

It is common knowledge that the costliest measures are those involving track structure modifications, such as replacing the link track with a tie-less track or applying sub-ballast mats. The cheapest changes in this case are changes in the building structure and replacement of doors and double-glazed windows, as well as reduction of train speed in the track section.

To resolve this issue, a major overhaul of the railway line would be the most effective solution; otherwise, this measure is not justifiable. The data suggests that there are no upcoming significant track repairs, thus, let's analyze them using a table 1.

Table 1 shows the combination of protective measures, which are relevant and appropriate in this case. The combination of these measures in this case achieves the normative values for noise.

Table 1. Combination of noise protection measures, dBa.

Variant number	Noise absorbing panels	Thickened double-glazed windows	Continuous rails	Special rail covers	Noise screens	Noise protection galleries	Reducing the speed of the train	Application of composite pads	Application of sub-ballast mats	Total
1	10	10	-	-	15	-	-	10	-	45
2	10	-	-	-	-	25	5	10	-	50
3	-	10	-	-	-	25	5	10	-	50

4 Results and discussion

Considering the three proposed options, we can conclude that the most optimal, effective, economically workable is option №1 with the use of thickened double-glazed windows, noise-absorbing panels, noise screens, use of composite pads.

5 Conclusion

Thus, in order to select the optimal and cost-effective choice of noise protection measures for residential buildings near the railway, it is necessary to carry out a comprehensive assessment of the existing conditions and indicators. It is important to consider that the cost of the measures should not go beyond the overall cost of demolition and resettlement.

References

1. Noise in Europe 2014. EEA Report № 10/2014, https://www.eea.europa.eu/publications/noise-ineurope-2014

2. M. V. Butorina, D. A. Kuklin, P. V. Matveev, A. Yu. Oleynikov, Vestnik RGUPS **2**, 57 (2019)
3. Guidelines for the selection of noise protection measures when identifying excess acoustic impact from railway transport facilities (approved by Order of JSC Russian Railways dated October 12, 2022 N 2638/r)
4. M. Butorina, L. Drozdova, D. Kuklin, Approacgothe rail noise reduction, in Proceedings of 24th International congress on sound and vibration - ICSV–2017. St. Petersburg : International institute of acoustics and vibration, (2017), p. 5
5. I. A. Yaitskov, Theoretical study of the vibrations transmitted to frame from internal combustion engine of locomotives and diesel locomotives and their influence on labor conditions of locomotive crews, in Proceedings of the 4th International conference on industrial engineering, lecture notes in mechanical engineering ICIE–2018, p. 2375–2384
6. S. S**.** Bortsova, Noise Theory and Practice **8(2)**, 45 (2022)
7. A. N. Beskopylnyi, A. N. Chukarin, B. Ch. Meskhi, D. Dzhedirov,Experimental studies of noise and vibration during milling of cast iron parts, in E3S Web of Conferences. International Scientific Conference Transport Technologies in the 21st Century (TT21C-2023) "Actual problems of Decarbonization of Transport and Power Engineering: Ways of Their Innovative Solution", (2023), p. 04082.
8. A. N. Beskopylnyi, A. N. Chukarin, P. S. Kurchenko, A. Isaev, Substantiation of systems for reducing noise and vibrations of grinding wheels in the processing of bodies of transport vehicles, in X International Scientific Siberian Transport Forum - TransSiberia 2022, Vol. "Transportation Research Procedi" (2022), p. 2529-2534
9. S. A. Solod, V. V. Novikov, A. E. Litvinov, A. N. Chukarin, Structuring information on the state of labor safety at mechanical engineering enterprises, in IOP Conference Series: Materials Science and Engineering, "International Scientific and Practical Conference Environmental Risks and Safety in Mechanical Engineering, ERSME 2020", (2020), p. 012112.
10. S. S**.** Bortsova, Noise Theory and Practice **7(3)**, 42 (2021)
11. I. A. Yaitskov, Vestnik RGUPS **1**, 27 (2018)
12. A. N. Chukarin Yu. I. Bulygin, L. N. Alekseenko, V. A. Romanov, Integrated development of noise-dust woodworking machines at the design stage, in IOP Conference Series: Earth and Environmental Science (2017), p. 012014