1. Introduction

Road and rail transport today are the inevitable satellites of human civilization. According to studies conducted in Russia and Europe, on the scale of acoustic impact road and rail transport take the first and second places. Rail transport compared with other types of transport, has several advantages by the impact on the environment. However, the railways seriously increase the acoustic pollution of the environment and often adversely affect the population. From 50 to 70% of the population in developed and developing territories is subject to the harmful effects of noise from railway transport. Noise is a health hazard, causing the risk of cardiovascular diseases, reduced performance, neuropsychiatric diseases, anxiety and discomfort. It is not uncommon for motorways and railways to pass close to each other. So, residential areas are subject to the combined effects of noise from both road transport and railways. Therefore, the issue of developing effective noise reduction measures in such situations is becoming increasingly important.

The most convenient source of information about the acoustic situation in the territory of settlements is a noise map. Noise maps should be compiled for all highways with a traffic intensity of more than 3 million cars per year and railways with a traffic intensity of more than 30 thousand trains per year [1].

Noise maps for the current period, used to assess the existing noise regime, are performed in order to exclude, prevent or reduce the harmful effects of road and railway noise on humans and the environment. To this end, on the basis of uniform noise control methods, they draw up operational noise maps, on the basis of which they identify zones of acoustic discomfort and develop organizational, technical and con-
struction measures to protect population from noise. Operational noise maps, developed as part of projects for the reconstruction of existing and construction of new objects of road and railway transport, allow us to estimate the acoustic situation for the planned period and select the necessary noise protection measures for the adjacent residential area. Thus, noise maps are also an effective tool for monitoring and controlling noise.

As an example of the use of noise maps for separating the contributions of various noise sources to the general acoustic situation, this article considers the territory of the village situated in the Leningrad Region, where the railway and roads pass in the close vicinity of residential buildings [2].

2. Development of noise maps

To assess the impact of noise on the adjacent residential area, noise maps were created using the SoundPLAN software. The noise mapping process includes:

1. collection of data on noise sources;
2. drawing up a terrain model (relief, buildings, premises);
3. calculation of noise propagation;
4. analysis of the data and development of recommendations.

At the first stage, the noise characteristics of the railway and roads were determined. The noise characteristics of the traffic were obtained by carrying out field measurements in accordance to national method presented in state standard [3]. The measurements were carried out during the hours of maximum traffic intensity in the daytime and at night. When measuring the traffic noise, the microphone was located at a height of (1.5 ± 0.1) m, at a distance of (7.5 ± 0.2) m from the axis of the nearest lane and was directed towards the traffic flow. The measurement sites were selected on sections of streets and roads with a steady velocity of vehicles and at a distance of at least 50 m from intersections, transport areas and stopping points of passenger public transport. Ten roads with the highest traffic intensity were selected as the main sources of noise. According to the results of measurements, the noise characteristics of the traffic (equivalent sound levels at a distance of 7.5 m from the axis of the nearest lane) were equal to 59-76 dBA at daytime and 55-72 dBA at night.

The noise characteristic of the railway transport was calculated in accordance to national method presented in state standard [4]. On this section of the railway three categories of trains pass: high-speed trains, electric trains and freight trains. Trains were distributed evenly for day and night time. Taking into account the intensity and speed of movement, the noise characteristic of the railway transport was calculated. The equivalent sound levels of the flow of rail transport at a distance of 25 m from the axis of the nearest track were equal to 74 dBA both at the daytime and at night.

With the help of topographic maps containing information on the heights of the site, such as Yandex and Google, a terrain model was developed taking into account the features of the relief and building. It allowed us to obtain a complete picture of noise distribution at the territory.

When developing a noise map, the territory was divided onto receivers with a grid with a step of 10 m. After determining noise levels at receivers, points with equal sound levels were connected by isolines, as a result of which lines of equal sound level were obtained with a step of 5 dBA, which corresponds to the requirements of noise limitation [5].

A noise map of the territory of the village adjacent to the railway is presented in fig. 1 providing equivalent sound levels at night. As the noise map shows, due to the common influence of the roads and the railway, a significant part of the territory adjacent to the railway is in the zone of impact of high noise levels. According to the results of the calculation of noise levels at the facades of residential buildings, the excess of noise limits in dwelling was evaluated reaching 20 dBA during the daytime and 28 dBA at night, which indicates the need to develop noise protection measures.
Since there are two main sources of noise in the territory under consideration, it is necessary to determine which of them makes a greater contribution to the overall situation and, accordingly, which impact should be reduced first of all.

To separate the contributions of noise sources, noise maps were constructed separately for roads and railway. There are noise maps for the railway and the roads in fig. 2 and 3 presenting the equivalent sound levels at night.

Excess of equivalent sound levels above limits for the daytime by different sources are:
- 0,5-17,0 dBA for railway transport;
- 0,5-13,6 dBA for road transport;
- 0,1-20,1 dBA for total noise exposure.

Excess of equivalent sound levels above limits for the night time by different sources are:
- 1,1-27,5 dBA for railway transport;
- 0,5-21,6 dBA for road transport;
- 3,3-28 dBA for total noise exposure.
Figure 2: Noise map railways

Figure 3: Noise map for roads
3. Development of noise protection

On the basis of the calculations, we can make a conclusion that the railway makes a greater contribution to the acoustic situation in the territory under consideration. In view of this, two variants of noise protection measures were proposed. To protect the population from noise and reduce it on the territory and in residential premises, noise protection barriers and noise protection glazing were recommended. As the first variant, it was proposed to install noise protection barriers 5.5 m high along the railway on both sides, thereby reducing the noise of the railway, and to implement noise protection glazing for houses where an excess of noise limits is still observed. As the second variant, it was proposed to install noise barriers along the railway on the south side (barrier’s height is 5.5 m) and along the highway on the north side (barrier’s height is 5 m), thereby reducing the impact of both the railway and the road, and also install noise protection glazing.

In order to determine which variant of noise protection would be the most effective, noise maps were developed taking into account noise protection. In fig. 4 a noise map with account of noise protection according to the first variant is presented.

Figure 4: Noise map according to the first variant of noise protection

It is obvious from the map that, despite the fact that it was not possible to reduce noise to the limit, the noise levels in the territory near the dwellings on the south became noticeably lower. According to the results of calculations the excess of noise limits makes only 14.3 dBA. However, in the north, the road noise still creates large excess in the adjacent territory. The equivalent sound level at night is exceeded by 23 dBA.

Noise map was also developed for the second variant of noise protection. It is shown in Fig. 5. With this option, the excess of limit values in the territory will be up to 12 dBA. Such allocation of noise
protection barriers is more efficient and, despite the fact that it does not allow to achieve limit noise values it significantly reduces noise at the whole territory.

![Noise map](image)

**Figure 5:** Noise map according to the second variant of noise protection

## 4. Conclusion

When developing noise protection measures for areas where the main sources of noise are both rail and road, one needs to have a clear idea of a contribution each source makes to the overall acoustic situation. In the considered example, when the roads and railways pass in close proximity to each other in the residential area, it is insufficient to reduce noise of the only noise source. Development of a complex of barriers intended to reduce both road and railway noise and combined with the use of sound-proof glazing allows us to achieve obvious reductions in noise levels.

Today, the most convenient way to separate the contributions of noise sources is to create a noise map. Having considered the noise maps for the railway and the road separately, it is possible to assess which source causes the greatest noise level exceeding the limit value in the territory. It is also possible to develop a set of noise protection measures to reduce a common effect of both noise sources.

## REFERENCES


