Impact of the city transport noise on the territory close to the streets’ intersection

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Abstract. The city of Krasnodar has a complex structure of highways. The noise generated by transport significantly exceeds the standard values. Territories located at the crossroads of streets have not been studied thoroughly. The process of spreading sound from sources at the intersections of roads is more complex. The development of additional recommendations for noise reduction for such areas is required. The results obtained are of practical interest for areas with similar placement conditions with respect to highways. Our research and developed recommendations for reducing traffic noise in residential and public buildings can be widely applied in design practice. The experimental studies in real conditions on the characteristic territory of the city of Krasnodar using current regulatory documents were performed. The research is executed experimentally with carrying out the measurements in the territory and theoretically settlement way. The good convergence of results confirms their reliability. Impact of noise in the territory of directly adjacent to the intersection, is slightly higher than values for the sites at rectilinear roads. It is established that noise pollution at a facade of the designed house does not conform to requirements of sanitary standards. The required noise reduction in rooms taking into account their appointment is established. Practical recommendations about noise reduction in inhabited and office rooms are developed. The proposed solutions will allow providing additional protection of rooms against transport noise.

Introduction
Noise is one of the main factors influencing a condition of the surrounding environment. Actuality of this problem is that the systems of highways in large cities of the world develop actively. For three decades the number of bars of motion have been grown on motorways [1]. The amount of transport vehicles grows and the assistance of government steadily appears in the development of difficult transport communications [2, 3]. Such tendency conduces to the increase of a transport noise level from different sources [4, 5]. In the residential areas the noise may cause serious diseases [6, 7, 8].

Noise control measures should be carried out at the design stage. It is important to have accurate information about the degree of noise pollution in areas designated for construction.

The city of Krasnodar has a complex structure of highways. Sources of noise are cars, trolley buses, trams. In the central part of the city there are two railway stations. In the immediate vicinity of
the residential development there are two airfields. We have previously conducted the studies in certain city areas. The results of these studies showed that the noise generated by the transport significantly exceeds the standard values [9].

It should be noted that in most cases, recommendations for carrying out measures for noise protection refer to areas located along the straight part of the transport route [10]. For those located at intersections of territories, the development of additional recommendations is required. In these areas, the very process of spreading sound from sources is more complex.

In this paper, the study of traffic noise in the area immediately adjacent to the intersection of city roads. The required additional noise reduction has been determined. Developed recommendations for the protection of premises from traffic noise have been carried out.

**Materials and methods**

The experimental method is accepted as the main one. The experiments were performed in real conditions. The studies were performed in compliance with the basic requirements of regulatory documents [11, 12].

The tests were performed for the territory located at the intersection of two Yalta and Ural streets in the city of Krasnodar. The object under study corresponds to the typical situation of the residential area should be provided for the noise protection [13, 14, 15].

The main sources of airborne noise are the trunk roads of regional significance along the streets of Yalta and Ural, inter-quarter passage on Borodin Street. The background noise is influenced by the remote section of the Krasnodar Sorting Station - Tikhoretskaya.

To estimate the actual noise mode, the noise characteristics of non-constant noise are used - the equivalent sound level is $L_{Aeq}$, dBA and the maximum sound levels are $L_{Amax}$, dBA. The noise characteristics of a single vehicle passing to the parking lots in the yard area of a residential building and a gas station have the following meaning. For passenger cars $L_{Aeq}$ is 67 dBA, and $L_{Amax}$ is 77 dBA. For the trucks cars respectively: $L_{Aeq}$ is 67 dBA, and $L_{Amax}$ is 77 dBA [13, 14].

During the tests, the methods and requirements of the documents were observed [11, 12]. Measurements were carried out at 3 points in areas with steady speed of movement of transport. The first two points characterize the trunk roads. The third point characterizes the passage along Borodin Street.

During the tests, the methods and requirements of the documents [13 - 20] were observed. The measurements were carried out at three points in the areas with a steady speed of the transport movement. The first two points characterize the trunk roads. The third point characterizes the passage along the Borodin Street. Experimentally obtained noise characteristics of highways can reliably establish the level of noise in the territory. Then it is necessary to determine the noise levels in the area directly adjacent to the building. The initial data are the experimentally obtained values. For the sound level definition, the building method of the theoretical calculation is applicable.

On the areas close to the designed building set points (S.P.) in which the expected sound-level is ($L_{A,R,T}$). The size of this sound-level corresponds to the equivalent sound-level in dBA. The method of calculation of this size allows, knowing noise description of motor transport stream, to take into account the decline of noise from the row of factors.

In our study the several design points were taken. This method will allow to characterize the impact of transport highways at the building’s design stage.

It is important to note that the assessment of noise pollution near the surface of the earth will differ significantly with elevation. The calculations were carried out at several levels, taking into account the
number of floors of the high-rise buildings. The design points (DP) are selected at the middle level of the windows at a distance of 2 meters from the building facade.

The calculation of the required noise reduction in the room is made according to the equivalent value of the expected sound level at the calculated points. The required reduction of noise penetrating the premises is made for apartments and offices.

The experimental measurements show the real situation on the noise characteristics of the noise main sources. The results of transport streams noise characteristics measurements are given in Table 1. For comparison, Table 1 gives the normalized values of sound levels in the territory.

Comparison of the measured values of noise characteristics with normalized values was performed. Noise characteristics of traffic flows on the streets of Yalta and Ural significantly exceed the standards. The reliability of the research performed, is confirmed by the calculation. The data obtained allow to predict the changes in the acoustic environment in subsequent years. The calculated values of the expected sound levels at the facade of the designed building are obtained. It is established that at the level of the middle of the windows of the first floor the sound level is 69 dBA.

Table 1. The traffic flow noise characteristics

| Measurement location | Measuring point | Daytime  | Measured values | Normalized values |
|----------------------|----------------|----------|-----------------|------------------|
|                      |                |          | Equivalent level, $L_{Aeq}$, [dBA] | Maximum level, $L_{Amax}$, [dBA] | Equivalent level, $L_{Aeq}$, [dBA] | Maximum level, $L_{Amax}$, [dBA] |
| Ural                | T. 1           | night    | 71              | 80               | 45               | 60               |
|                     |                | day      | 74              | 82               | 55               | 70               |
| Yalta               | T. 2           | night    | 73              | 82               | 45               | 60               |
|                     |                | day      | 74              | 84               | 55               | 70               |
| Borodino            | T. 3           | night    | 60              | 66               | 45               | 60               |
|                     |                | day      | 63              | 69               | 55               | 70               |

Calculations of the equivalent expected sound levels at the facade for the residential part of the building show that the sound levels at the calculated points at the midpoint of the windows of the fifth and sixteenth floors differ by 8 dBA. On the sixteenth floor, the highest equivalent expected sound level of 65 dBA will be in the central part of the main facade. On the top floor, at the front of the front apartment with a window facing Yalta Street, the equivalent sound level is 64 dBA, and at the front of the front apartment with a window facing the Ural Street, the equivalent sound level is 60 dBA.

The highest sound levels according to the calculation, will be on the fifth floor. In the central part of the main facade, the equivalent expected sound level is 68 dBA. At the facade of the front apartment with a window facing the Yalta street, the equivalent sound level is 67 dBA, and at the facade of the front apartment with a window facing the Ural street, the equivalent sound level is 62 dBA.

The calculation of the expected equivalent sound level in the yard showed that its value is 58 dBA and exceeds the required value, both for day and night time. The maximum sound level is 77 dBA.

Further calculation of the required reduction of noise penetrating into the dwelling premises was made according to the highest value of 68 dBA obtained for the fifth floor. The calculation for nonresidential premises on the ground floor is made on the highest value 69 dBA.

As a result of the calculation the expected levels of sound generated by the transport, it was found that noise pollution at the facade of the designed house does not meet the normalized requirements [13, 14, 15].

From the side of the main facade, at an equivalent sound level, the excess is 14 dBA during the daytime, and 24 dBA at nighttime. On the territory, the courtyard noise levels are lower compared with the values from the main facade.
At the equivalent sound level, the excess is 3 dBA during the daytime and 13 dBA at nighttime. Maximum noise level $L_{A_{max}}$ exceeds normalized values in the daytime by 7 dBA, and at night by 17 dBA.

Summary

The practical recommendations made on the basis of this study are as follows. When designing high-rise buildings in areas located at intersections, it is necessary to make experimental measurements of the noise characteristics of the main sources of noise. This will allow to obtain accurate values for further calculations. In the conditions of the southern climate, the best solution is to create forced ventilation of rooms and air conditioning. This will allow the permissible levels of external noise in the buildings to increase the rate of ensuring the permissible levels in the premises with the windows closed. The maximum value of the required sound insulation of the windows of residential premises should be at least 28 dBA. Window designs in the usual version cannot provide the required sound insulation for the residential premises.

The studies of modern window systems have shown that when used in buildings, noise protection windows and multi-glazed windows will provide a standard noise mode in residential areas [16, 17].

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