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Research of Levels of Noise Generated by Road Traffic in Urban Areas

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Abstract. This article presents a correlation graph of noise levels vs traffic intensity and vs height of buildings, as well as vs distances from motorways based on results of carried out research; simulation models of exposure to noise levels in areas with high traffic intensity (more than 3,000 vehicles/hour) have been generated using the "ACOUSTIC" software package. Based on the obtained empirical correlation graphs recommendations have been developed aimed at reducing noise levels created by transport. A nomogram was generated to determine the noise levels generated by high traffic intensity motorways in both front-facing and ribbon types of residential blocks arrangement. The recommendations provide means for designing noise baffles to be placed near the medium to high traffic intensity motorways taking into account noise levels with respect to building heights in urban areas, as well as respecting the residential blocks arrangement and the overall heights of buildings.

1. Introduction

The main noise source in cities, including Tyumen, is motor transport [1, 13]. Tyumen is a fast growing city and the Tyumen Region is in the top ten regions having the highest vehicle-to-population ratio. According to forecasts this figure will be close to 510 cars per 1000 citizens by 2025 [12-19].

The total area of Tyumen is 235 square kilometers, the total length of roads is about 300 km. The constantly growing number of cars poses a problem of arranging the city's road network. Including finding a solution of how to expand existing "problematic" areas, how to construct multi-level road crossings, etc. All these activities contribute to the fact that the noise sources (traffic) draw nearer to the residential buildings in the urban areas [1-11]. The change in traffic intensity on the existing sections of the road network will result in noise level changes in these areas. Hence, the noise environment in the residential areas adjacent to the traffic, inherently unfavorable, gets even worse [2-10].

Therefore, it is necessary to study noise levels in the districts of Tyumen having various traffic intensity in correlation with the height of buildings and at various distances from individual areas, taking into account the type of residential blocks arrangement relative to the motorway. This will allow the administration and the citizens to acquire data on the noise levels in the areas, conduct noise levels monitoring when assessing the noise pollution in residential areas, assess the background noise levels in any part of the city, which will be necessary in determining specifications of mandatory noise protection measures (acoustic baffles), as well as will be useful during a design of a new building [18, 20].



2. Formulation of the problem

The objective of this study is to enhance safety of urban areas effected by noise from motorways of various traffic intensity in cities with various types of residential blocks arrangement.

In order to achieve this objective, it is necessary to resolve the following tasks:

- to study the traffic intensity and noise levels of traffic flows on various types of motorways;
- to measure experimentally the road traffic noise in five districts with various intensity of traffic and type of residential blocks arrangement;
- to obtain empirical correlation graphs of noise level vs traffic intensity and height above ground, as well as vs distance from motorways;
- to simulate the exposure to noise levels in "ACOUSTIC" software package in areas with high traffic intensity (more than 3000 cars/ hour) and compare the obtained simulation results with results of field studies;
- to provide recommendations for reducing noise levels generated by traffic taking into account the obtained empirical correlation graphs.

Thus, it is necessary to develop methods for calculating the distribution and reduction of noise levels in residential areas of the city of Tyumen generated by traffic flows in various types of district arrangement plans, as well as to compare the noise levels simulation results with the results of field studies.

3. Solution of the problem

The study covers 5 districts of Tyumen - low (812 vehicles/hour) and medium traffic intensity areas (1620 vehicles/hour) and 3 high traffic intensity areas (3752 cars/hour and more):

- 1) Tovarnoye highway, Pervomaiskaya Street, Granitnaya Street (low intensity 812 vehicles/hour);
- 2) Respubliki and Melnikaite Streets intersection (medium intensity of 1620 vehicles/hour);
- 3) intersection of 50 Let Ocyabrya - Profsoyuznaya Streets, intersection of Melnikaite – Shirotnaya (Melnikaite 129 and Melnikaite 135.); Traktovaya - Kolkhoznaya Streets (high intensity of 3752 cars/hour and more).

"Oktava-110A" noise meters were used to measure the noise levels in districts. The total of around 2000 noise level measurements were made in each residential district.

In districts with low traffic intensity the noise levels slightly exceed the norm by 5 decibels on the A scale (dBA) at a distance of 10 to 15 m from motorway, the courtyard noise levels do not exceed the norm during the daytime hours in residential areas.

Noise level measurements at the intersection of 50 Let Oktyabrya and Profsoyuznaya Streets showed exceedances in front of facades of residential buildings: measurements taken near the 50 Let Ocyabrya, 4 building exceeded the norms by 25-30 dBA, measurements near 13 Profsoyuznaya Street and 17 50 Let Ocyabrya buildings exceeded norms by 15-20 dBA.

Based on results of noise level measurements obtained within the boundaries of listed city districts, empirical correlation graphs of excess normative values of equivalent noise levels (L, dBA) vs traffic intensity (Q, cars/hour) have been developed (Fig. 1-2). These graphs correspond to the area of Respublika-Melnikaite street intersection and the area of 50 Let Ocyabrya – Profsoyuznaya street intersection.

This function (Fig. 1) provides means for predicting noise levels created by motor transport depending on various traffic intensity in urban areas, and can be used in construction of buildings near heavy traffic motorways. The noise levels, generated by medium and high traffic intensity motorways, were measured vertically along the height of the facade of buildings (Fig. 2-3). Exceeding values shown in Fig. 2 have been observed at the level of 2nd-3rd floors of the building (excess of 13 dBA, whereas 40 dBA is a norm for premises in the daytime, 55 dBA is a norm for residential areas during daytime). Fig. 3 shows clearly that the noise level exceeds the norm by 19 dBA and has been observed at the level of the 5th floor on the building's balconies.

In order to perform evaluation of road traffic noise impact at various distances from motorway 2 city districts with high traffic intensity were also selected: Melnikaite street motorway (ribbon type of

arrangement of residential blocks, height of buildings - 30 meters or higher) and the district of Traktovaya-Kolkhoznaya streets (front-facing type of residential blocks arrangement, buildings are up to 15 meters high). The results of measurements were used to develop correlation graphs of exposure to noise levels vs distance from the motorway, which is shown in Fig. 4-7 (where L is the noise level, dBA, R is the distance to the motorway, m).

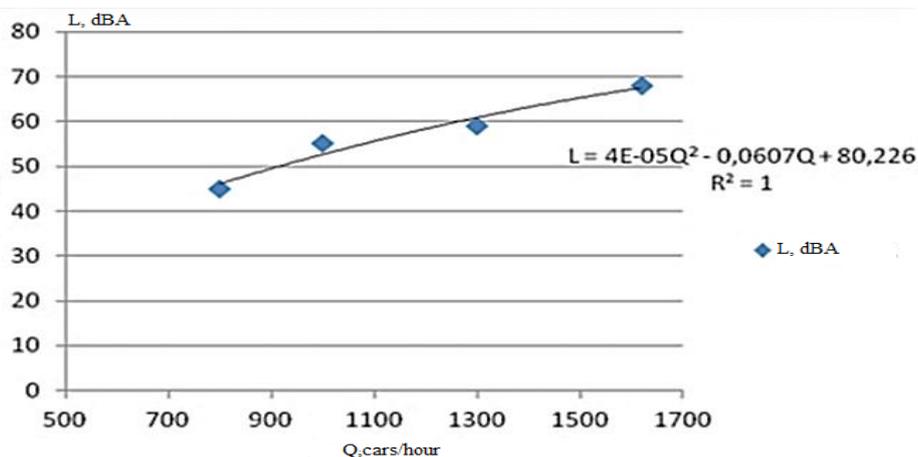


Figure 1. Empirical correlation graph of noise levels vs motorway traffic intensity.

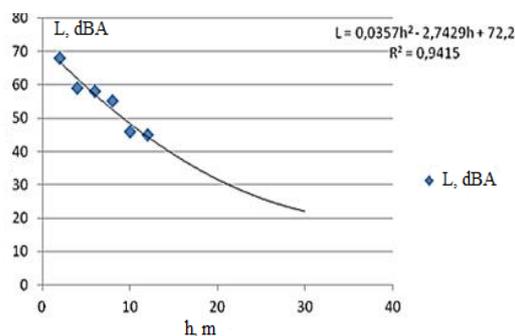


Figure 2. Correlation graph of noise level vs height above ground at the facades of buildings (h) near the road intersection with traffic intensity of 1620 cars/hour (Respubliky–Melnikaite streets), front-facing type of residential blocks arrangement (17 m).

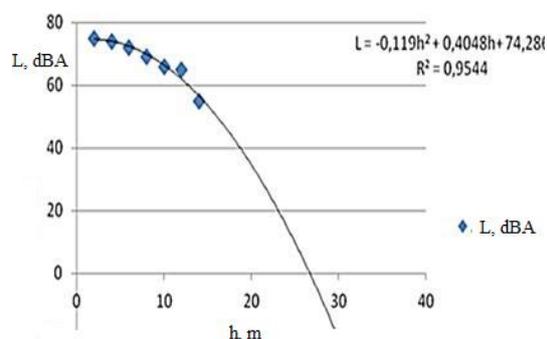


Figure 3. Correlation graph of noise levels vs height above ground at the facades of buildings (h) (traffic intensity 3752 cars/hour) near the intersection of 50 Let Octyabrya–Profsoyuznaya streets, ribbon type of residential blocks arrangement with gaps (17 m).

According to the results obtained by drawing an empirical graph of the noise level vs distance near the 129 Melnikaite Street building (Fig.4), the excess values can be observed at a distance of 80-90 meters from the motorway, whereas the highest excess in front of the facades of the building is 20 dBA. Thus, it can be concluded that at a distance of 45 meters there is a significant excess of noise during daytime by 25 dBA and during nighttime the excess values reach 10 dBA. With ribbon type of residential blocks arrangement having gaps between buildings the level of noise increases at a distance of 50 meters or more. This is due to the nature of reflection from building facades and amplification of acoustic waves (Fig.5). According to observations the norms are exceeded by 5-10 dBA within the courtyards of ribbon type of building blocks arrangement, in contrast to the front-facing arrangement of the same traffic intensity (the Traktovaya – Kolkhoznaya streets district). The noise propagation is

effected by the buildings height (Fig. 6,7). So with high-rise buildings (9 floors and higher) and the ribbon arrangement the noise level is reduced by 10-15 dBA.

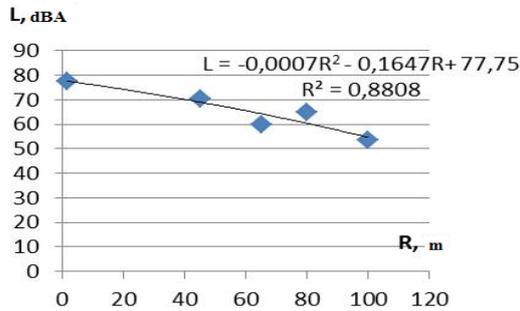


Figure 4. Correlation of noise level vs distance to the motorway with the ribbon type of residential blocks arrangement, 3565 cars/hour.

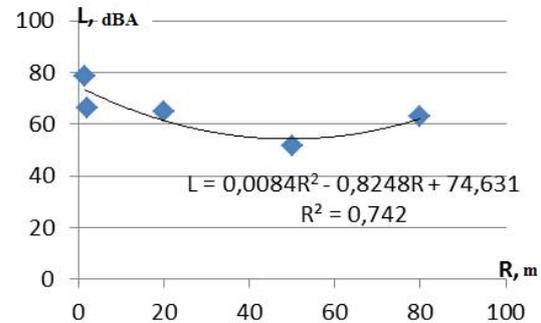


Figure 5. Correlation of noise level vs distance to motorway with ribbon type of residential blocks arrangement and gaps between buildings, 3565 cars/hour.

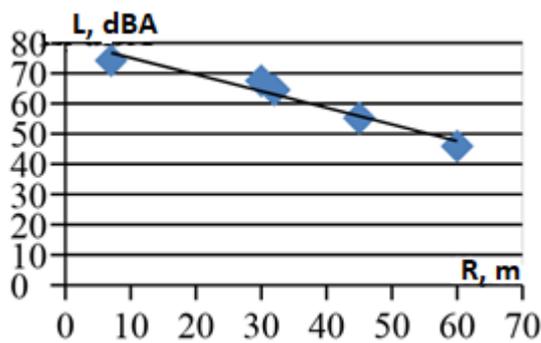


Figure 6. Correlation of noise level vs distance to the noise source with the front-facing type of residential blocks arrangement, 3600 cars/hour (the closest distance to a building is 19 meters).

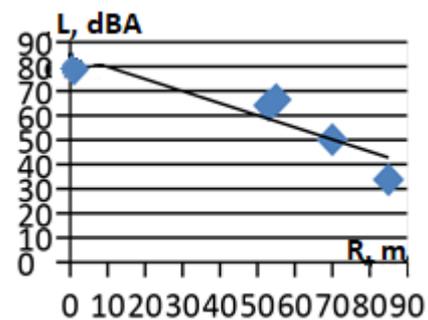


Figure 7. Correlation of noise level vs distance to the noise source with the front facing residential blocks arrangement, 3600 cars/hour (the closest distance to a building is 57 meters).

Fig. 6 shows the empirical graph of correlation of the noise level vs distance at the Traktovaya street motorway with the front-facing residential blocks arrangement type, where nearest building is located at a distance of 19 meters to the motorway, and Fig. 7 shows the similar graph of a building located at a distance of 57 m to the high traffic intensity motorway. Fig. 6-7 imply that the closer the first building with front-facing residential block arrangement is (15 meter high, up to 5 storeys) to the motorway the higher the noise level in that building is. And progressively as the distance gets bigger (above 50 meters) the noise level plummets sharply to the standard residential area values. At a distance of more than 57 m (Fig.7) to the motorway the noise level is still high and decreases at a distance of 70-80 meters. This means that in the areas where the buildings are low (up to 5 storeys) and where the type of residential blocks arrangement is predominantly front-facing the noise level exceeds the norms by 20-30 dBA near the buildings, as well as inside the courtyards by 10 dBA.

Calculations of the noise levels in the "ACOUSTICS" software package were made for those areas where full-scale field studies had been performed. Reference points were located in front of the facades of buildings and inside the courtyards. When comparing the calculated values with the field measurement results the difference of not more than 10% has been noted, when calculating the noise levels relative to the height of buildings the calculation difference was 15% (Table. 1, 2).

Table 1. Ribbon type of residential blocks arrangement.

Height, m	129 Melnikaite Street, traffic intensity, cars/hour	Field measurement results	Calculation results
1,5	over 3000	80	74
10	over 3000	65	62
15	over 3000	55	50
20	over 3000	45	40

Table 2. Front-facing type of residential blocks arrangement.

Height, m	Traktovaya Street, traffic intensity, cars/hour	Field measurement results	Calculation results
1,5	over 3000	80,5	74
10	over 3000	66	62
15	over 3000	48	50
20	over 3000	42	40

Noise level measured in the field is higher than the calculated one, especially along the building height and differs by 9 to 24% compared to the calculated values. Thus, the higher the reference point above ground, the bigger the difference in noise level from the calculated data. In case of the front-facing residential blocks arrangement the difference between the noise level measured in the field and the calculated ones ranges from 10 to 33%.

Based on the field measurement results a nomogram was generated (Fig.4).

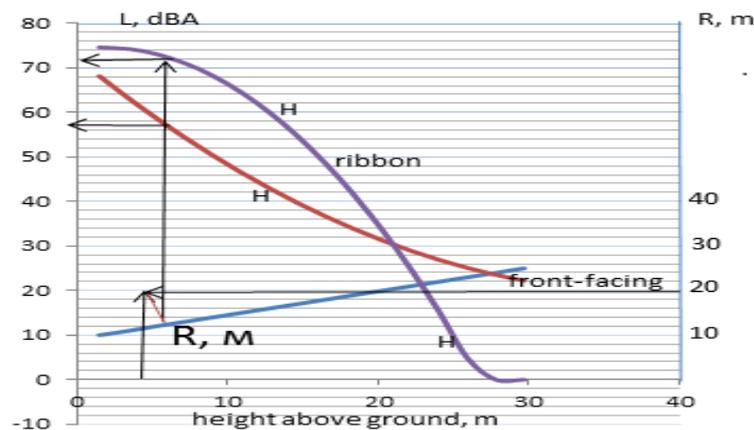


Figure 8. Nomogram generated to determine noise impact exerted by the traffic intensity above 3000 cars/hour vs the height of buildings and vs various distances.

Fig. 8 shows nomogram which provides means for determining noise levels with various types of residential blocks arrangement. The nomogram (Fig.8) enables prediction of noise levels relative to the height above ground (h , m) with respect to the motorway, which becomes important at designing a multi-storeyed building with varying number of storeys.

When working with the nomogram: 1. determine a traffic intensity, vehicles per hour; 2. determine a specific type of residential blocks arrangement in relation to the motorway (front-facing, ribbon type); 3. determine a distance $-R$ from a building to a motorway (to the facade of the building, the

right axis), in meters; 4. choose a height above ground, required in determining noise levels; 5. draw lines to intersect with R and H; 6. from the point of intersection draw a line to the R curve; 7. determine the noise level, dBA.

Thus, we can establish that some measures are required to reduce noise levels generated by motorways, taking into account the noise magnitude along the height of the building, the type of residential blocks arrangement, as well as the intensity of traffic.

4. Summary

1. As a result of the above experiment the correlation graphs of noise levels vs traffic intensity and the height of buildings above ground have been obtained. In case of front-facing residential blocks arrangement a gradual decrease in noise levels relative to the building height occurs, whereas exceeding noise values are observed up to the 5th storey, and in case of the ribbon type of arrangement a sharp reduction of noise levels occurs from the middle of the building.

2. Empirical correlation graphs of traffic intensity made it possible to predict the noise level generated by motor transport at different traffic intensity in the city, which can be used in the construction of buildings near motorways.

3. A nomogram has been generated to determine the impact exerted by noise of traffic with intensity of more than 3,000 vehicles/hour vs building height and vs various distances with ribbon and front-facing types of construction arrangement, which is necessary when designing shielding structures, and protective baffles near the buildings.

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