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Acoustic Safety of the Living Environment

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Abstract. Living in the city is affected by numerous factors, the action of which can cause harm to the human health. One of them is a noise pollution of the living environment by road transport. On the streets with intense traffic, noise levels often exceed the permissible values for the living environment. Various measures can be applied to reduce noise in residential areas, which will promote the extension of the period of active human activity, improve living conditions and increase in life expectancy. One of the most effective noise protection measures (especially in multi-storey buildings) is the use of windows with high soundproofing. There were conducted the studies of noise pollution of residential areas in Dnipro (Dnipropetrovsk). Experimental investigations were performed according to standard methods using modern acoustic measuring instruments. When obtaining data and processing the results there were used a special computer program to build noise maps in 3D (developed in Prydniprovska State Academy of Civil Engineering and Architecture) and methods of mathematical statistics. As a result of the research, a nomograph was constructed to determine the category of windows on different facades for different floors of the building. The nomograph enables to reasonably and quickly decide on the need to use windows with high soundproofing.

1. Introduction

A human in his nature always strives for a state of security and wants to make his existence as comfortable as possible. To ensure a certain level of quality of life, an artificial habitat is created. However, in this environment, due to human activities, there are many different factors (chemical, physical, social, psychological, etc.) that negatively affect human health.

Particular attention should be paid to factors related to environmental pollution. They can cause a number of environmental diseases and, in general, lead to a reduction in average expectation of life.

The noise pollution factor has a great influence on the quality of the urban environment. One of the main sources of pollution in the city is road transport. Noise pollution can cause significant socio-economic damage. Therefore, it is necessary to take noise protection measures to ensure acoustic comfort in residential buildings.

2. Relevance, scientific importance of the problem with a brief review of literature

During the design of new and reconstruction of existing residential construction, there is a question of providing the future area with a certain level of quality and safety of life, the main criterion of which is human health [1, 2, 3]. A particular attention should be paid to builders and designers on the issue of acoustic safety of housing development, as one of the main parts of environmental safety of the living environment. Many studies have been devoted to the problem of noise pollution in cities and the struggle against it [4-16]. They proved that noise pollution, today, is one of the most harmful physical factors that can have an effect on mind and cause various diseases.

In modern conditions, the social value of human health is increasingly growing. This shows a clear need for the selection and implementation of noise protection measures in all spheres of life-sustaining activity of the people. Measures to ensure acoustic comfort in residential areas are developed in three directions: 1) noise reduction at the source of its formation; 2) noise reduction on the way to its spread from the source to residential construction; 3) noise reduction in residential construction. In urban areas, the greatest impact of noise pollution is exposed to the population living in areas adjacent to main streets or roads. Under the conditions of an existing building it is not always possible to use certain noise protection measures of the first and second direction. Thus, for example, the use of noise screens very well protects low-rise buildings (1-2 floors), but is ineffective for multi-storey buildings [17, 18]. Increasing the height of the screen can lead to additional economic costs and reduce the aesthetic quality and safe operation of the building. Creating noise-protective zones of greenery along the streets allows reducing noise load and gas contamination in the surrounding areas. But often this measure cannot be performed due to the limitation of a territory. Moreover, the effectiveness of such zones depends on the length of the growing period of greenery [4,19-20]. That is why, for the first echelon of buildings, which can perform the functions of screen buildings (protect the rest of the territory), the most operational means of noise control is the use of windows with high noise insulation [21, 22].

Thus, the paper is dedicated to solving the current scientific and practical problem of providing acoustic safety in residential areas, by choosing the right category of windows for noise protection.

3. Task definition

In order to ensure acoustic safety in the residential accommodation of the first echelon of buildings by selecting and using windows with high sound insulation, it is necessary to analyze the noise pollution of the living environment from vehicles for different facades of the building and to build a nomograph to determine the category of windows.

4. Theoretical part

The most convenient method for determination of the noise mode of residential areas is to build noise profiles. When developing noise profiles, a large amount of work is required to determine the noise level of traffic flows on the streets of the city by instrumental or calculation method. Measurements should be carried out according to the standard method, during "peak" hours at rushes not closer than 100-150 meters from intersections and public transport stops, at wind speeds up to 3 m/s, at a distance of 7.5 ± 0.2 m from the axis of the first lane of traffic. Full-scale measurements of the equivalent noise level are performed using a noise level meter. The expected level of noise pollution on the main streets, according to DSTU-N B B.1.1-33: 2013 "Guidance on the calculation and design of noise protection of residential areas", can be determined by the formula:

$$L_{Aequivalent} = 44 + 0,26 \cdot V + 10\lg\left(\frac{N_3}{V_3}\right) + \Delta L_{Acovering} + \Delta L_{Adeviation} \tag{1}$$

where:
V – average speed of traffic flow on the race, km/h;
N_3 – composite (by sound energy) traffic intensity in units/hour;

V_3 – composite (relative to the speed of cars) average speed of traffic flow on the race, km/h;

$\Delta L_{Acovering}$ – amendment to the dBA, which takes into account the type of surfacing of the street or road;

$\Delta L_{Adeviation}$ – correction in dBA, taking into account the longitudinal slope of the street or road.

Permissible values of equivalent and maximum noise levels in the residential accommodation and in the areas directly adjacent to residential buildings for day and night are set by DBN B.2.2-12: 2018 "Planning and development of territories", DBN B.1.1-31: 2013 "Protection of territory, buildings and structures from noise" (table 1).

Table 1. Permissible noise levels.

Purpose of premises and type of territory	Time of day	Sound level, dBA	
		equivalent	maximum
Residential accommodation of apartments	Daytime	40	55
	Night-time	30	45
Areas directly adjacent to residential buildings	Daytime	55	70
	Night-time	45	60

Statistical processing of experimental data by noise was performed using a licensed program Microsoft Office Excel 2010. The most reliable is considered to be the average value of the measured value of the sound pressure level or sound level. The average value is formed both when averaging several results at one point on the measuring surface, and when averaging several results for different points [23].

$$L_{cp} = \frac{1}{m} \sum_{i=1}^{m} L_i \qquad (2)$$

where:
m – number of measurements;
L_i – the result of a separate measurement.

The error of an individual measurement is most often characterized by the root mean square value δ_m, obtained on the basis of a number of measurements, and the error of the mean value is determined by the value of the root mean square error of the result S_m.

$$\delta_m = \left(\frac{\sum_{i=1}^{m} (L_i - L_{cp})^2}{m-1} \right)^{1/2} \qquad (3)$$

$$S_m = \frac{\delta_m}{(m)^{1/2}} \qquad (4)$$

Similarly, when averaging out the values for different points on the surface, the confidential interval that characterizes the dispersion of average is narrowing with increasing number of points, and the measurement error is decreasing.

5. Practical significance, suggestions, and results of implementations, results of experimental studies

We have measured noise levels on the main streets of Dnipro with linear construction of buildings of the first stage of industrial construction (so-called "Khrushchev-era apartments", "Brezhnev-era apartment"), as well as processed and analysed the results. The current state of noise pollution on the main streets of the city shows that noise levels cover the range from 60 to 80 dBA. An example of processing experimental data on Polya Avenue is provided in table 2.

Table 2. Noise levels (dBA) of traffic flows moving along Polya Avenue

Average noise level, dBA	δ_m, dBA	Confidence interval, dBA	
		lower	upper
70,2	0,2	70,0	70,4

Using the obtained data, a large number of 3D models of noise profiles were built using the method (Zakharov Yu.I. program), which was developed at the SHEE "PSACEA" [24]. An example of 3D models of noise profiles along Polya Avenue is shown in figures 1, 2.

Classification of noise-protective windows by acoustic efficiency (dBA): A - window of normal construction in the "closed" mode ($\Delta L_A = 20$ dBA); A1 – the same in the "ventilation" mode ($\Delta L_A = 10$ dBA); B - noise-protective window ($\Delta L_A = 25$ dBA); C - noise-protective window ($\Delta LA = 30$ dBA); D - noise-protective window ($\Delta L_A = 35$ dBA); E - noise-protective window ($\Delta L_A > 35$ dBA).

After analysing the noise levels on the facades of buildings, we built a nomograph to determine the categories of windows (A-D) to ensure acoustic safety in the living space, which must be installed on different facades of the residential building from the first to the fifth floor (Figure 3).

The method of determining the category of windows that must be installed in a residential building (up to 5 floors) in order to ensure the acoustic safety with the help of nomographs in Fig. 3 is as follows:

1. It is necessary to use instrumental (for existing buildings) or calculation (for projects) methods, the level of noise pollution on the facade of the building from the side of the linear noise source LNS (the facade of the building is focused on the noise source - a street with heavy traffic).
2. On the axis "Noise level on the facade of the building from the side of LNS " it is necessary to select the value of the noise level obtained according to paragraph 1 and go up to the line (I, II, III, or IV) of the selected facade.
3. Move parallel to the axis "Noise level on the facade of the building from the LNS" to the line of the corresponding floors (lines 1, 2, 3, 4, 5).
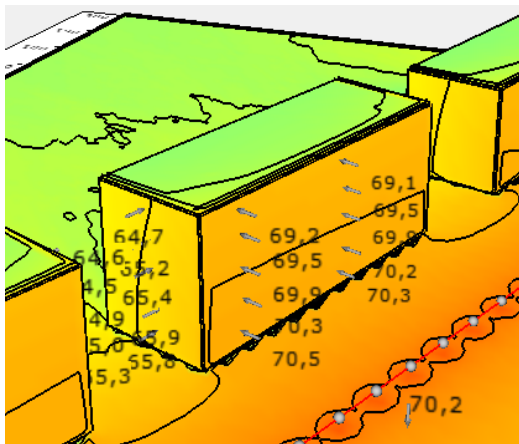4. Go down and determine the desired category of windows.

Figure 1. Chart of noise pollution of a residential building (up to 5 floors) on Polya Avenue (the facade is oriented to the noise source and the gable facade).
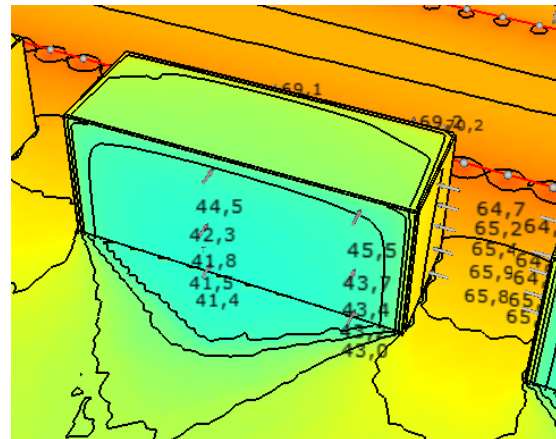

Figure 2. Chart of noise pollution of a residential building (up to 5 floors) on Polya Avenue (elevation facing yard).
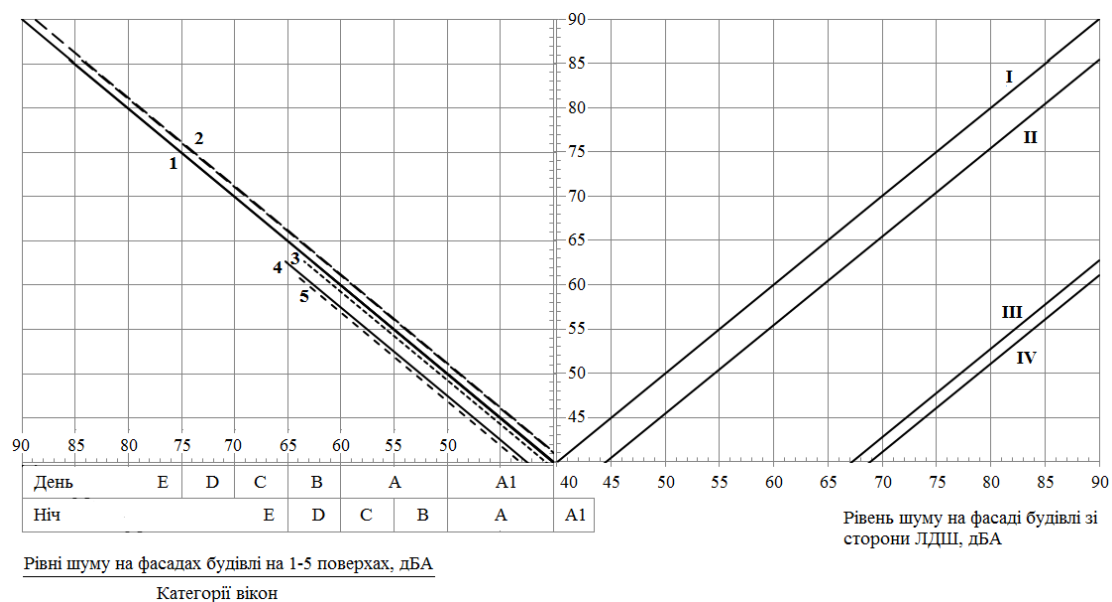

Figure 3. Nomograph for the determination of the category of windows by acoustic efficiency (AD in dBA) on different facades of the building (contact-junctural zone (CJZ) up to 12 m). I - the facade of the building is directed on the noise source (main street); II - gable facade of the building; III - elevation facing yard of the building (the first row of windows from the corner of the house); IV - elevation facing yard of the building (windows in the middle of the facade of the house); 1 - first floor for I, II, III, IV; 2 - the fifth floor for I, II; 3 - the fourth floor for III, IV; 4 - fifth floor for III; 5 - fifth floor for IV.

6. Conclusions

Noise levels on the main streets of the city of Dnipro cover the range from 60 to 80 dBA.

One of the most effective methods of providing acoustic safety in the living accommodation is the use of noise-protective windows that is why as early as the design stage it is necessary to consider

what category of windows should be installed in residential buildings, especially those directed on the streets with intense traffic.

The express method of determining the required category of windows by their acoustic efficiency (A-D in dBA) on different floors for different facades of the building has been developed, that provides the opportunity to significantly reduce the time for calculations and more reasonably determine the installation of the required category of noise-protective windows in the building.

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