This paper reports the improved model for estimating transport noise from highways at a roadside lane under the influence of noise load from traffic flow moving on an open section of the highway and over a bridge.

It has been established that with an increase in the distance from the sound source to the coordinates of the noise load measurement, the noise decreases, both in the presence of a noise-protective screen and in the case of an open section of the highway. At 100 m from the sound source, the noise load level decreases by 13.4 % in the case of the car moving over a bridge, and by 13.3 % when driving a car along an open section of the road.

It has been found that the noise level on bridges exceeds the level of noise pollution from the road to 10 dB, which is explained by the propagation of different frequencies of noise load from the bridge.

It has been determined that due to the special nature of sound waves, diffraction through noise screens does not change all frequencies evenly. High frequencies diffract to a smaller degree while lower frequencies diffract deeper into the "shadow" zone behind the screen. Therefore, the screen is more effective at reducing sound waves with a high frequency compared to sound waves with lower frequencies.

Experimental studies into the effectiveness of noise-protective screens made of metal perforated structures on sections of public roads were carried out, taking into consideration distances from noise sources to noise load measurement sites.

It is established that noise-proof screens made of steel (perforated) sheet reduce the level of noise load from vehicles to the environment by up to 14 %.

It was found that when driving cars on the road, the equivalent sound level at a distance of 1 m in front of the noise protection screen is 88.6 dBA while the maximum sound level at a distance of 1 m in front of the noise protection screen is 103.9 dBA.

It has been established that in the presence of a drain hole in the noise protection screen, its acoustic efficiency is reduced to 3 dBA

Keywords: highways, transport facilities, noise loads, protective screens, acoustic characteristics, traffic flow

UDC 626/627

DOI: 10.15587/1729-4061.2022.253389

DETERMINING REGULARITIES IN THE DISTRIBUTION OF NOISE LOAD FROM MOTORWAYS AND ROAD BRIDGES DEPENDING ON THE DISTANCE TO A RESIDENTIAL AREA

Sergii Laslov
Corresponding author
Researcher
Department of Bridges, Tunnels and Hydraulic Structures
National Transport University
M. Omelianovycha-Pavlenka str., 1, Kyiv, Ukraine, 01010
E-mail: sl25051982@gmail.com

Oleksndr Tokin
PhD, Associate Professor, Professor
Department of Production, Repair and Materials Science
National Transport University
M. Omelianovycha-Pavlenka str., 1, Kyiv, Ukraine, 01010

Artur Onyshchenko
Doctor of Technical Sciences, Associate Professor
Department of Bridges, Tunnels and Hydraulic Structures
National Transport University
M. Omelianovycha-Pavlenka str., 1, Kyiv, Ukraine, 01010

Received date 03.01.2022
Accepted date 01.02.2022
Published date 25.02.2022

How to Cite: *Laslov, S., Tokin, O., Onyshchenko, A. (2022). Determining regularities in the distribution of noise load from motorways and road bridges depending on the distance to a residential area. Eastern-European Journal of Enterprise Technologies, 1 (10 (115)), 55–64. doi: https://doi.org/10.15587/1729-4061.2022.253389*

1. Introduction

Along with the environmental pollution by toxic substances from exhaust gases, the level of acoustic pollution from road transport is rapidly increasing. This is due to a significant increase in the intensity of road traffic, an overall increase in the power of car engines, and an increase in driving speeds.

Noise has become one of the main pollutants of the environment. Doctors consider noise a common biological stimulus because all organs of the human body react negatively to an increase in noise levels. Noise load results in that a person is feeling fear, discomfort, excessive excitement, which in turn negatively affects the relationship between people.

In the European Union, noise pollution of settlements and suburban areas is considered one of the most serious environmental problems.

The World Health Organization (WHO) has proposed standard noise level directive values for an average external situation of 55 dBA, which are acceptable during normal daytime to prevent significant interference with the livelihoods of the population. The regulatory criteria for issuing noise on transport are still far from the values recommended by WHO, due to the lack of opportunities for their technical and financial support.

The noise load that a person receives causes fatigue, irritation. In addition, with large enough amplitudes of sound, nonlinear distortions occur in the human auricle: higher harmonics in the case of sinusoidal tone, combination tones with a non-sinusoidal tone.

Studies indicate an adverse effect of noise on the central nervous, cardiovascular, and digestive organs. Violation of the state of functioning of the central nervous system under the influence of noise leads to a weakening of attention and performance, especially mental [1].

The maximum permissible level of transport noise in the United States on the territory directly adjacent to residential development is 70 dBA.

International norms adopted in the countries of the European Community define the level of 82 dBA as the maximum permissible for a car of any type.

Paper [2] states that Resolution 1776 (2010) of 12 November 2010 on Noise and Light Pollution [3] of the Parliamentary Assembly draws attention to the problem of environmental, in particular noise and light pollution of the European continent.

In Japan, for example, the main characteristic of the noise of motor vehicles is the noise level when they are accelerated. For trucks, the standards set permissible noise levels from 89 dBA to 83 dBA, depending on the carrying capacity and engine power. In the future, it is expected to reduce this level by 6–9 dBA. For passenger cars, the noise level allowed is 82 dBA, perspective – 78 dBA [4].

In France, when assessing traffic noise, the level of repetition is 50 %. In the zone of existing highways, the noise level of 68 dBA is permissible, for new roads – 65 dBA [4].

The task of reducing the impact of road noise on the surrounding area today must necessarily be considered in projects for the construction and reconstruction of highways.

The noise from the movement of vehicles on the road has three sources: exhaust noise, noise of engines and tires interacting with the road surface. This noise is partially jammed by the design of the coating and the soil base of the road.

In the case of traffic flow moving along the bridge, the intensity of the noise load becomes even greater due to two reasons: the resonant phenomena of the bridge structure and the considerable height of the noise source. Works [5, 6] state that the noise from transport on bridges is more intense than the noise of the ground road and covers a larger area. In addition, the noise on the bridges is not so jammed by the coverage of the carriageway, and can even increase depending on the design and size of the span structure. Protective screens on bridges should be placed on the zone structure, that is, be an element of the bridge structure.

Obviously, the problem of noise pollution in the case of bridges should be considered as a specific task in the general problem of environmental protection. To do this, noise load models should be developed that will make it possible to formulate requirements for noise screen structures that are designed on bridges and highways.

Therefore, research on the development of methods for assessing noise load from vehicles moving on the road and bridge is relevant.

2. Literature review and problem statement

Work [6] states that the noise load from road transport is significant. In the traffic zone, it is equal to a jet plane at an altitude of 300 m and then dampens very slowly. Because the atmosphere cannot significantly affect the reduction of the propagation of the sound wave. At a distance of 90 m, its power can be damped only by 6–10 dB, depending on atmospheric conditions.

It is established that in dry air, at a temperature of 0 °C, the speed of sound is 331.5 m/s, and with an increase in temperature – it increases. It is also established that the fading of the sound wave is significantly affected by the humidity of the medium. The higher the humidity, the faster the sound wave spreads.

Work [7] provides parameters for the dependence of the relative change in the speed of sound on moisture, at a constant temperature. It was found that the greater the humidity, the faster the sound wave spreads.

However, works [6, 7] do not address the noise load that arises from vehicles moving on the bridge. In addition, no studies have been conducted on the distribution of noise load, depending on the distance to the noise protection screen.

Studies in [8] have found that on high-speed roads, a 2-fold reduction in the average speed of a car can lead to a decrease in the equivalent noise level by 5–6 dB. This is one of the methods of reducing noise load. However, no studies of the noise load on the surrounding areas from the movement of vehicles on the bridge have been carried out.

Owing to the research reported in [9], it was established that noise reduction can be achieved using the appropriate configuration of the tyre pattern and the design of the car tyre. However, the design of tires with a significantly reduced noise level contradicts the need to ensure traffic safety, prevent tyre heating, and ensure the efficiency of the car.

It should be noted that works [8, 9] report studies of noise load in the movement of vehicles on the road. However, no studies have been conducted when moving cars over the bridge and the patterns of propagation of the sound wave depending on the distance to the sound source are not taken into consideration.

Thus, great opportunities to reduce noise on highways in the area of transport facilities indicate the creation of promising alternative structures of the road surface.

Important, from the point of view of noise restriction, is the structure of the road surface itself. Namely, whether it is formed by a bituminized material with a random pattern of the structure, or a concrete coating, with a dominant transverse structure.

In the UK, studies were conducted [10] that established the ratio between the resistance of the car adhesion on the road surface and the total noise level generated by cars driving at high speeds on the road surface. Studies [11] found that this ratio does not statistically depend on the structure of the material of the road surface. However, there is a contradiction between determining the road surfaces with a low noise level and satisfactory safety standards at high speeds. This is due to the fact that a smooth road surface can be low noise but at the same time absolutely dangerous for movement in wet weather.

Works [10, 11] do not provide procedures for determining noise in the case of road transport on the bridge.

Laying an experimental road surface on the corrugated surface of concrete sections of a ring road laid east of Brussels [11] has led to lower noise levels. The noise level decreased to 4 dBA for cars moving at a speed of 70 km/h and 5.5 dBA at a speed of 120 km/h. In addition, it is established in the cited work that the reduction of noise level can be achieved with other types of porous road surfaces. However, studies of noise loads when driving cars on the bridge have not been carried out.

In Sweden, noise load data were obtained when applying porous road surface [11], and in work [12] – composed of stone island with emulsifying asphalt selected by granulometric composition as binder. In Canada, the distribution of noise load is obtained for the road surface, composed of a mixture of “open type”, with a thin protective layer of bitumen [11]. It was found that the noise level decreased by 4–5 dBA compared to the noise level on roads with normal asphalt pavement. And it decreased by 3 dBA compared to the worn concrete coating, which has much less resistance to lateral wear than the road surface, composed of an "open type" mixture covered with a thin protective layer of bitumen.

However, Norway and Sweden faced problems [4, 11, 12] associated with wear resistance of these road surfaces, which is caused by the use of tires with spikes in the winter months. These tires crush the surface layer into a fine powder, which then clogs the pores of the "open type" road surfaces, gradually reducing their sound absorption.

Work [10] addresses the development of scientific and methodological foundations of acoustic calculation and architectural and constructive design of noise-protective screens, taking into consideration their planning and design solutions and volumetric and spatial characteristics of the facility, which should protect against traffic noise.

Works [11, 12] consider the basic solutions to the problem of noise protection: a basic assessment of general noise protection measures and the world experience of noise protection measures. The experience of different countries in the use of noise protection means both on existing roads and on the roads being designed, built, and analyzed the effectiveness of various noise protection means is described.

Work [13] reports world experience in the design and production of noise-proof screens. In addition, the analysis of the types and structures of noise-protective screens, their use in world practice, and the features of the design and installation of various types of noise-protective screens, their noise protection and performance characteristics are given.

Work [14] highlights the principles of efficiency of using noise protection screens and methods for calculating the effectiveness of noise protection screens. Local and special conditions that are not specified in the regulatory documents and their impact on the calculation of the effectiveness of noise protection screens are discussed.

Paper [15] provides basic information about the design and materials of noise-protective screens, some features of their device and operation in the United States and Russia.

Article [16] describes different types of noise protection screens, taking into consideration their impact on the environment. The connection between the ecological and aesthetic component in the design of noise protection screens is given. The problems of visual perception of the screen, integration of the structure with the uncharacteristic, for the environment, shape, deterioration of natural movement of air currents, violation of the existing landscape during construction, etc. are highlighted.

In work [17], it was established that an important parameter in assessing the effectiveness of noise-protective properties of screens is their height. The height of noise protection screens should be at least 1 m. Noise from road cars are low-frequency vibrations with a frequency of 50–200 Hz, which corresponds to wavelengths of 7.2–1.8 m. A 7 m high screen is required to protect against noise with such frequencies.

Work [18] shows the features of the installation and operation of noise protection screens, as well as considers additional requirements put forward in the design of screens in the United States.

In [19], a study of noise load from urban traffic and an assessment of its impact on humans, using geospatial technologies, was carried out. However, no noise load assessment was carried out from vehicles when driving on the bridge.

Work [20] developed basic principles for determining the sound wave when it is distributed in a viscous soil environment. However, no noise load characteristics have been obtained.

The basic principles of the influence of dynamic load on the speed of propagation of the sound wave are shown in [21].

In work [22], with the help of sound waves, an assessment of the degree of compaction of crushed rubble ballast of the road is performed; and in [23], it is established that under the action of a dynamic load, the magnitude of the sound wave increases when passing through a homogeneous environment.

However, there is no assessment of the impact of the sound wave on the environment in works [19–23].

Paper [24] describes noise monitoring systems that pollute large cities. It is established that in order to protect the population from noise, it is necessary to monitor the places of the greatest noise load and choose noise protection systems.

However, the cited work did not assess the impact of noise from the movement of cars on transport structures.

Work [25] assessed the parameters of traffic flows based on the processing of localization data on the movement of vehicles in the city. However, no studies of noise load on the environment have been carried out.

Papers [26–28] provide data on the spread of noise load on urban pollution by road and rail vehicles. Studies [29, 30] provide models for forecasting noise load in cities based on the intensity of traffic flows.

In [31], the U. S. Environmental Protection Agency (EPA) and the World Health Organization (WHO) state that to build noise maps, it is necessary to use forecasting methods based on the number of rail vehicles that have passed, as well as their type.

Ensuring the required level of acoustic comfort is one of the main tasks of environmental protection for densely populated regions of states with a developed transport infrastructure with high intensity.

However, despite the high level of acoustic pollution of the surrounding areas, protective devices on bridges that would protect the environment from noise load are rarely designed. It should also be noted that there are no studies of noise transport load on the environment when driving on bridges. It should also be noted that the above authors did not conduct studies of the fading of the sound wave, depending on the distance to the source of noise and the distance to nearby residential buildings. That requires further research and is an urgent task.

3. The aim and objectives of the study

The purpose of this work is to determine the patterns of distribution of noise load arising from highways and bridges during the action of traffic flows, taking into consideration the distance to the noise source and the coordinates of noise measurements, which will make it possible to assess the impact of noise load on adjacent areas.

To accomplish the aim, the following tasks have been set:

– to investigate noise load from vehicles when driving on open sections of highways and over a bridge, taking into consideration and without taking into consideration noise protection screens and noise load measurement coordinates;

– by experimental measurements of noise load from vehicles on public roads to determine the noise load on the surrounding areas depending on the distances to noise protection screens and residential buildings and the technical condition of the screens.

4. The study materials and methods

4. 1. Methodology of experimental measurements of noise load

The locations of measurements of the effectiveness of noise protection screens were determined on the basis of preliminary field surveys. At the same time, the places that were closest to residential buildings were chosen.

Noise measurements were carried out in dry weather (without precipitation) and on the dry surface of the highway.

Measurements of noise characteristics of traffic flow were carried out on 238 km of the Kyiv-Chop highway in order to determine the effectiveness of noise protection screens.

Equipment for measuring noise from traffic flows is specified in Table 1.

Table 1

List of equipment for measuring noise from traffic flows

Specification	Measured parameter	Measurement range	Measurement error
1. Noise meter Octava 110A	Noise	30–130 dB (A)	±1 dB (A)
2. Electronic weather station, type WM-918	Air temperature	(–40–0) °C (0–40) °C	±2 °C ±1 °C
	relative humidity	(25–40) % RH (40–80) % RH (80–90) % RH	±7 % RH ±5 % RH ±7 % RH
	atmospheric pressure	(795–1050) mbar	±7 mbar
3. Vane anemometer, ASO-3	Wind speed	0.2–5,0 m/s	0.35 m/s
4. Meter, ZPKZ-20AUT/1	Linear dimensions	0÷20 m	±0.5 mm

The place of measurements was selected on sections of streets and roads with a constant speed of vehicles and at a distance of at least 50 m from intersections, transport areas, and stop points of passenger public transport.

Measurements were carried out on condition that the surface of the roadway of streets and highways was clean and dry and were carried out in the absence of precipitation and at wind speeds of less than 5 m/s. At wind speeds of more than 1 m/s to 5 m/s, a cap was used to protect the measuring microphone from the wind in order to weed out the noise load from the wind.

The measurement time was set during periods of maximum traffic intensity. It was 432 cars per hour.

When measuring the noise characteristics of the traffic flow, which included cars and trucks, road trains, buses (hereinafter referred to as cars), the measuring microphone was located on the sidewalk or bypass. The distance of placement was 7.5±0.2 m from the axis closest to the point of measurement of the lane or path of movement of the vehicle at an altitude of 1.5±0.1 m from the level of coverage of the roadway. Under conditions of dense construction, the measuring microphone was located at a distance of less than 7.5 m from the axis closest to the point of measurement of the lane or path of movement of the vehicle. However, no closer than 1 m from the walls of structures, continuous fences, and other structures or elements of relief that reflect the sound.

In addition, noise load measurements were additionally carried out in the case of the location of the street or road in the notch. In this case, the measuring microphone was installed on the edge of the notch at a height of 1.5±0.1 m from ground level.

The measuring microphone was directed towards the traffic flow. The operator who carried out the measurement was at least 0.5 m from the measuring microphone.

The period of measurement of the noise characteristics of the traffic flow, which included cars, motorcycles covered the passage of at least 200 transport units in both directions. The process of measuring the noise level is shown in Fig. 1.

a

b

Fig. 1. Determining noise level: *a* – in front of the noise protection screen, 238 km of the Kyiv-Chop highway; *b* – near a residential building in the place of installation of a noise-proof screen

Next, according to the results of the measurements, statistical processing of the results of measurements of road parameters and noise level on them was carried out according to the program of multiple correlation-regression analysis.

4. 2. Models for assessing traffic noise in a roadside traffic lane

Using mathematical dependences (regression equations), built from the statistical modeling of noise level, intensity, and speed of movement, it is possible to construct a linear model for assessing transport noise from traffic flows.

To construct a mathematical model, the estimated equivalent noise level from the traffic flow at a distance of 7.5 meters from the axis of the nearest lane with a coating of fine-grained asphalt concrete on a segment with zero inclination is determined from the formula:

$$L=50+8.8 lgN, \tag{1}$$

where L is the equivalent noise level, dBA; N – perspective intensity of movement, car/h.

Our result takes into consideration a correction to the composition of the transport flow since trucks and buses with a carburetor and diesel engine generate different noise levels. Depending on the state of the surface over which the noise is propagated, and the distance of the reference point from the axis of the lane, the value of the correction is found from the formula:

$$L=10K_p \lg\frac{L+L_m-7.5}{L_m}+\frac{\alpha\cdot 1}{100}, \tag{2}$$

where 10 is the correction to the calculation to the axis of the lane, dBA; K_p – a coefficient that takes into consideration the absorption of sound by surface cover; L is the distance from the calculation point to the nearest lane; α – the absorption rate of sound in the air; L_m is the distance from the point of 7.5 m to the axis of the equivalent lane, m.

The restrictions that are taken into consideration when solving the task of improving acoustic comfort include the effective height of the notch slope, which is determined from the formula:

$$h_{ef} = \frac{l(H-h_1)-(k+m)(H-h_1+h_2)}{\sqrt{l_2+(H-h_1+h_2)^2}}, \tag{3}$$

where H is the notch depth; h_1 is the height of the geometric center of the noise source above the road surface, m; k is the distance from the estimated axis of the lane to the border of the slope or barrier, m; m is the projection of slope on the horizontal plane, m; h_{ef} must be at least 0.1 m.

The point of determining the noise level should be distanced from the edge of the notch at a distance not less than the depth of this notch:

$$(k+m+H) \le l. \tag{4}$$

It should be noted that for practical purposes of noise assessment, it is advisable to use a logarithmic pressure measurement scale in decibel units (dB). The ratio between these units is given by the following formula:

$$SP = 10\lg\left(\frac{P}{P_{ref}}\right)^2, \tag{5}$$

where SP is sound pressure; P is the value of sound pressure in the μPa; P_{ref} is the lower value of sound pressure, P_{ref} =20 μPa.

The reverse transition is given by the following formula:

$$(P/Pref)^2=10^{(SP/10)}. \tag{6}$$

According to [2], the calculation of the fading of the sound wave is carried out according to the following formula:

$$P_t = P_i \exp(-0.1151\alpha S), \tag{7}$$

where P_t is the sound pressure, Pa; P_i is the initial sound pressure, Pa; S – the length of the trajectory of sound propagation, m, or km; α – the coefficient of sound fading, due to sound absorption by the atmosphere, dB/m, or dB/km, which is calculated from the following formula:

$$\alpha = 8.686 f^2 \left\{ \left[1.84\times10^{-11}\frac{p_r}{p_a}\sqrt{\frac{T}{T_0}}\right] + \left(\frac{T}{T_0}\right)^{-5/2} \times \left[\frac{0.01275\exp\left(\frac{-2239.1}{T}\right)}{f_{r0}+\left(\frac{f^2}{f_{r0}}\right)} + \frac{0.1068\exp\left(\frac{-3352}{T}\right)}{f_{rN}+\left(\frac{f^2}{f_{rN}}\right)} \right] \right\}. \tag{8}$$

The coefficients included in equation (16) are calculated according to the following formulas:

$$f_{r0} = \frac{p_a}{p_r}\left(24+4.04\cdot10^4 h\frac{0.02+h}{0.391+h}\right), \tag{9}$$

$$f_{rN} = \frac{p_a}{p_r}\sqrt{\frac{T_0}{T}}\left(9+280h\exp\left\{-4.170\left[\left(\frac{T_0}{T}\right)^{\frac{1}{3}}-1\right]\right\}\right), \tag{10}$$

$$h = h_r\frac{p_r}{p_a}10^C, \tag{11}$$

$$C = -6.8346\left(\frac{273.16}{T}\right)^{1.261} + 4.6151. \tag{12}$$

In these formulas, f is the frequency of sound (Hz); T is the atmospheric temperature (°C); T_0 is the relative temperature, which is taken equal to 20 °C; h_r – relative humidity (%); p_a – atmospheric pressure (kPa); p_r is the relative atmospheric pressure, one atmosphere, taken equal to 101,325 kPa.

In the case of noise protection screens, it is necessary to take into consideration the fact that noise-protective screens reduce traffic noise due to absorption, change in wavelength, reflection, or diffraction. Diffraction, or bending with sound waves of interference, can occur both at the top of the screen and around it.

The difference in trajectory lengths is used to determine Fresnel number (N_0), which is a dimensionless value used to predict the weakening of sound, a noise-proof screen located between the source and the receiver. The Fresnel number is determined from the following formula:

$$N_0 = \pm 2\frac{\delta_0}{\lambda} = \pm\frac{f\delta_0}{c}, \tag{13}$$

where N_0 is Fresnel number; ± is a plus if the sound propagation line between the source and the receiver is lower than the diffraction point and the minus point, when the propagation line is higher than the diffraction point; δ_0 is the difference in the length of trajectories, m; λ – the length of the sound wave emitted by the source, m; f is the frequency of sound emitted by the source, Hz; c is the speed of sound, m/s.

If the difference in trajectory lengths and Fresnel's number increase, then the potential of the screen increases.

The amount of sound transmitted by the screen can be described by the indicator "loss of sound transmission" (TL). Losses of screen sound transmission are determined from the following formula:

$$TL = 10\log_{10}\left[10^{(SPL_s/10)}/10^{(SPL_c/10)}\right], \tag{14}$$

where SPL_s is the sound pressure level on the source side, dB; SPL_τ is the sound pressure level on the side of the receiver, dB.

Next, the calculation of the fading of the sound wave was carried out using formula (7) to determine the coefficients according to formulas (8) to (12). This took into consideration the temperature of the atmosphere and the relative temperature, which is taken equal to T_0=20 °C; relative humidity and atmospheric pressure. The relative atmospheric pressure in one atmosphere was taken equal to 101,325 kPa.

In the presence of a noise protection screen, the loss of screen sound transmission was taken into consideration according to formula (14).

5. Results of studies of noise load under the action of vehicles

5. 1. Results of estimation of noise load distribution from movement of vehicles on highways

The results of the assessment of the spread of noise load from the movement of a car on an open road and on a bridge relate to the nearest lane to the house. When calculating, the following initial data were taken: the type and condition of the road surface of the asphalt pavement, flat, the surface of the road surface is dry. Ambient parameters: air temperature, 30.2 °C; humidity, 70.5 %; atmospheric pressure, 745 mm Hg; and wind speed, 1.2 m/s.

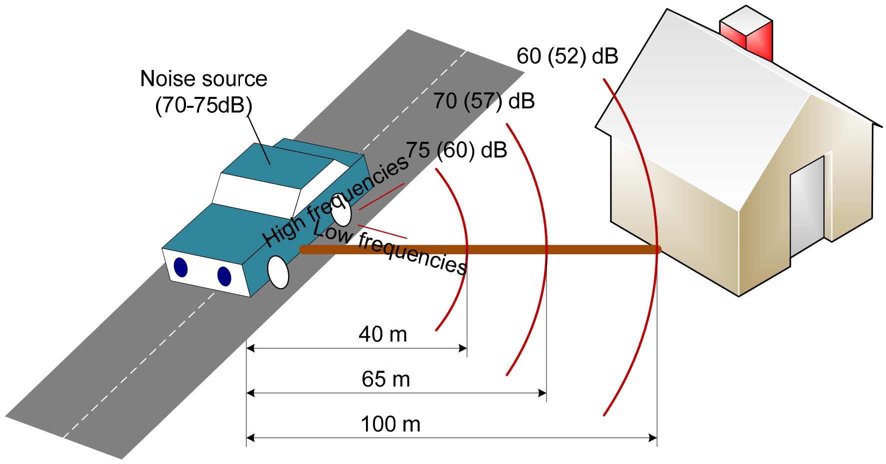

Fig. 2. Noise load when driving a car on an open section of a highway

In Fig. 2, 3, the noise load values given in brackets are noise load values in the presence of noise protection screens. When calculating them, the loss of sound transmission of the screen is taken into consideration according to formula (14).

The results of the distribution of noise load, depending on the distance from the sound source to the noise measurement coordinates, showed that with an increase in distance, the noise load decreases, both in the presence of a noise protection screen and in the case of an open section of the highway. In the case of a car moving on an open section of the road at a distance of 40 m from the sound source, the noise load is 75 dB, and in the presence of a noise protection screen – 60 dB, at a distance of 65 m, respectively, 70 dB and 57 dB and at a distance of 100 m – 60 dB and 52 dB.

In the case of a car moving on a bridge with a sound source of 80–85 dB, the noise load at a distance of 40 m without the presence of a noise shield on the bridge is 72 dB, and in the presence of a noise protection screen is 70 dB, at a distance of 65 m noise load, respectively, is 70 dB and 65 dB and at a distance of 100 – 67 dB and 58 dB.

As a result of our theoretical calculations of the fading of a sound wave according to formula (7) while determining the coefficients according to formulas (8) to (12), it was established that the noise level in the roadside lane is significant. And at a distance of 100 m from the vehicle, it is 60 dB in the case of traffic on an open section of the road. In the presence of a noise protection screen, the noise load decreases and is 52 dB.

The results of the spread of noise load from the movement of the car, which are shown in Fig. 2, 3, demonstrated that the noise level on bridges exceeded the level of noise pollution from the highway to 10 dB. It is established that at a distance of 100 m from a moving car, the noise load level is 67 dB, and in the presence of a noise protection screen on the bridge, the noise level decreases to 58 dB.

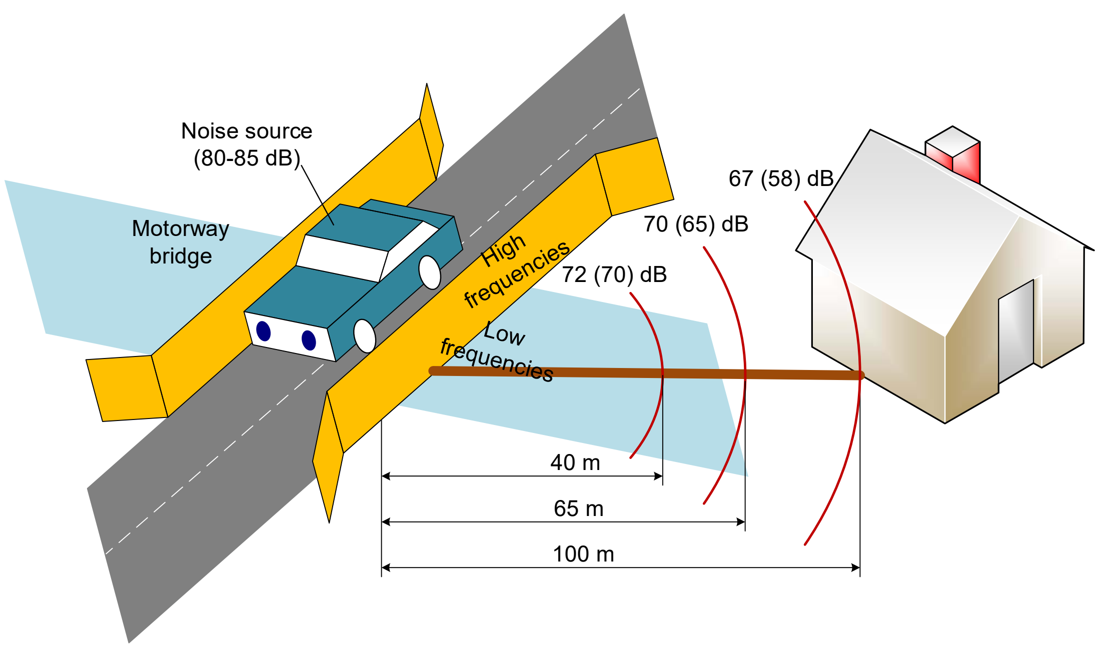

Fig. 3. Noise load when driving a car on a motorway bridge

5. 2. Experimental measurements of noise characteristics of traffic flow and noise on a motorway

The results of our experimental measurements of the acoustic efficiency of noise-protective parameters of screens located on the roads in the Rivne oblast are given in Table 2.

As a result of our experimental studies, it was found that the equivalent level of sound on the territory directly adjacent to residential development at a distance of 2 m is 74.4 dBA. At the same time, the maximum sound level on the territory directly adjacent to residential development at a distance of 2 m is 78.0 dBA.

In addition, our experimental measurements have established that the equivalent sound level at a distance of 1 m in front of the noise shield is 88.6 dBA, and the maximum sound level at a distance of 1 m in front of the noise protection screen is 103.9 dBA.

Table 2

Results of experimental measurements of acoustic efficiency of noise-protective parameters of screens (NPS)

Section of the highway with NPS, km	NPS length, m	Equivalent noise level before NPS, dBA	Equivalent noise level at 2 m behind NPS, dBA	Efficiency, dBA
261+527.1–261+598	70.9	85	71	14
274+540–274+610	70	84	70	14
285+215–285+275	60	86	73	13
285+485–285+550	65	85	73	12
288+320–288+400	80	86	73	13
288+655–288+980	325	86	71	15
289+110–289+210	100	86	70	15
289+350–289+430	80	85	71	14
289+110–289+210	100	84	69	15
289+500–289+675	175	85	69	16
296+950–297+130	180	86	71	15
297+180–297+230	50	86	74	12
297+320–297+695	375	88,6	71	15
297+730–297+910	180	85	69	16
297+995–298+460	465	86	70	16
300+500–300+560	60	86	74	12
301+738–301+815	77	84	71	13
306+850–306+905	55	85	73	12
306+925–306+960	35	85	74	11
307+000–307+070	70	85	73	12
315+200–315+260	60	86	74	12
315+300–315+480	180	86	71	15
315+580–315+840	260	86	70	16
315+940–316+010	70	87	74	13
316+760–316+860	100	85	70	15
317+260–317+530	270	85	69	16
318+700–318+820	120	86	71	15
319+230–319+360	130	86	71	15
320+100–320+195	95	86	72	14
320+620–320+763	143	87	72	15
322+500 (direction Rivne-Kyiv 0+154–0+224)	70	86	73	13
322+500 (direction Rivne-Kyiv 1+050–1+136)	86	86	72	14
398+248–398+286	48	86	74	12
261+750–261+830	80	85	72	13
296+780–296+980	200	86	71	15
297+595–297+790	195	85	69	16
297+850–297+910	60	86	75	11
298+030–298+090	60	86	75	11
314+700–314+930	230	86	71	15
315+600–316+155	555	86	70	16
315+240–315+470	230	87	72	15
315+470–315+530	60	85	74	11
320+290–320+460	170	85	70	15
363+440–363+473	35	85	74.4	11
363+488–363+542	54	86	75	11
363+551–363+612	61	86	75	11
363+620–363+659	39	86	78	11

It should be noted that the minimum and maximum noise level depend, to a large extent, on the type of transport and the intensity of traffic at different periods of the day.

It was also found that the equivalent sound level at a distance of 2.4 m behind the noise protection screen is 70.7 dBA, and the maximum sound level at a distance of 2.4 m on the noise protection screen is 89.8 dBA. From the above, we can conclude that the acoustic efficiency of this screen is 16–18 dBA.

At a distance of 19.5 m from the existing highway and at a distance of 2 m to residential development: the measured equivalent noise level exceeded the established regulatory value by 19.4 dBA. At the same time, the measured maximum noise level exceeded the established regulatory value by 8.0 dBA.

Experimental measurements taken to determine the noise load when driving cars over a bridge showed that at a distance of 40 m from the sound source, the equivalent sound level was 85 dB, at a distance of 65 m – 79 dB, and, at a distance of 100 m, 72 dB. It should be noted that the additional noise load from the bridge occurs due to the hits of the wheels of vehicles into the deformation seams.

As a result of our experimental studies, it was found that damage to the screen leads to a decrease in its noise-protective properties.

In the presence of a gap between noise-protective screens and the execution of the drain hole in the "classical" way (Fig. 4), it leads to a decrease in the acoustic efficiency of the screen to 3 dBA.

Fig. 4. Drain hole in the noise protection screen

6. Discussion of noise load results

The level of noise load from traffic flows is influenced by the intensity of traffic, longitudinal and transverse profiles of the road. In addition, the distance between highways, the presence of noise-protective objects and the operational condition of the carriageway.

The calculation of the fading of the sound wave according to formula (7) while determining the coefficients according to formulas (8) to (12) showed that with an increase in distance, the noise load decreases, both in the presence of a noise protection screen and in the case of an open section of the highway (Fig. 2, 3). In the case of a car moving on an open section of the road at a distance of 40 m from the sound source, the noise load is 75 dB, and in the presence of a noise protection screen – 60 dB, at a distance of 65 m, respectively, 70 dB and 57 dB, and at a distance of 100 m – 60 dB and 52 dB.

In the case of a car moving on a bridge with a sound source of 80–85 dB, the noise load at a distance of 40 m without the presence of a noise shield on the bridge is 72 dB, and in the presence of a noise protection screen is 70 dB, at a distance of 65 m noise load, respectively, is 70 dB and 65 dB, and, at a distance of 100, 67 dB and 58 dB.

It should be noted that at a distance of 100 m from the source of noise (passenger car) with a size of 70–75 dB, the noise level is 60 dB in the case of traffic on an open section of the road (Fig. 2). In the presence of a noise protection screen, the noise load decreases and is 52 dB. In the case of a car moving on a bridge at a distance of 100 m from a noise source of 80–85 dB on the bridge, the noise level is 67 dB, and in the presence of a noise protection screen on the bridge, the noise level decreases to 58 dB.

Thus, the noise-proof screen made of metal (perforated) sheets reduces the noise load level to 10 dB.

It is established that the noise level on the bridges exceeds the level of noise pollution from the highway to 10 dB. This is due to the fact that the span structure of the bridge emits noise vibrations, due to the effect of rolling stock. Significant noise emitters are also deformation seams, supporting parts, span structures, slabs of the carriageway.

It has been established that in the presence of a drain hole in the noise protection screen, its acoustic efficiency is reduced to 3 dBA.

The distribution of noise load in the case of cars on the open road and on a bridge is different. In the case of the road, when the source of noise is at the level of the earthen bed, higher frequencies are more effective, and low frequencies are mostly absorbed by the soil. In the case of a bridge – where the source of noise is at a considerable distance from the ground – along with high frequencies, low frequencies also affect a person. The length of the sound wave with low frequencies is greater than with high, therefore it covers a longer range.

The results of our experimental studies of noise characteristics (Table 2) of noise protection screens on the road in the Rivne oblast showed that the equivalent level of sound on the territory directly adjacent to residential development at a distance of 2 m is 74.4 dBA. At the same time, the maximum sound level on the territory directly adjacent to residential development at a distance of 2 m is 78.0 dBA.

In addition, our experimental measurements have established that the equivalent sound level at a distance of 1 m in front of the noise shield is 88.6 dBA, and the maximum sound level at a distance of 1 m in front of the noise protection screen is 103.9 dBA. The minimum and maximum noise levels depend largely on the mode of transport and the intensity of traffic at different times of the day.

Our studies found that it is relevant to protect the surrounding areas from noise that occurs when cars move over a bridge, since the amount of noise load on bridges exceeds the noise load level from the road to 10 dB.

It should also be noted that the results of theoretical studies of the spread of noise load would hold only for a passenger car and in sunny weather. In the case of changes in weather conditions, additional research should be carried out.

The development of methods for studying the noise level in the roadside lane from the value of the longitudinal slope and the average flow rate may be a further direction to advance our study.

7. Conclusions

1. It has been established that the noise level on bridges exceeds the level of noise pollution from the highway to 10 dB. At a distance of 100 m from a passenger car, the noise load level decreases by 13.4 % in the case of a car moving over a bridge and by 13.3 % when driving a car on an open section of the road.

The results of our studies have shown that with an increase in the distance from the sound source to the coordinates of the noise load measurement, the noise load decreases, both in the presence of a noise-protective screen and in the case of an open section of the highway. In the case of a car moving on an open section of the road at a distance of 40 m from the sound source, the noise load is 75 dB, and in the presence of a noise protection screen – 60 dB, at a distance of 65 m, respectively, 70 dB and 57 dB and at a distance of 100 m – 60 dB and 52 dB.

In the case of a car moving on a bridge with a sound source of 80–85 dB, the noise load at a distance of 40 m without the presence of a noise shield on the bridge is 72 dB, and in the presence of a noise protection screen is 70 dB, at a distance of 65 m noise load, respectively, is 70 dB and 65 dB and at a distance of 100 – 67 dB and 58 dB.

2. As a result of our experimental measurements, it was found that the equivalent sound level at a distance of 1 m in front of a metal (perforated) noise protection screen is 88.6 dBA, and the maximum sound level at a distance of 1 m in front of the noise protection screen is 103.9 dBA, which is greater than the normative value of 70 dBA. It was also found that the equivalent sound level at a distance of 2.4 m on the noise protection screen is 70.7 dBA, and the maximum sound level at a distance of 2.4 m on the noise protection screen is 89.8 dBA. Thus, the acoustic efficiency of the noise-protective screen from the material of steel (perforated) sheet, which is operated on the road in the Rivne oblast, is 16–18 dBA.

In the presence of a drainage hole in the noise screen, its acoustic efficiency is reduced to 3 dBA.

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