Paper No.374/2021

NOISE REDUCTION MEASURES DEVELOPMENT OF CONSTRUCTION SITES IN RESIDENTIAL BUILDING AREAS

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***Abstract**: An article discusses the problem of noise reduction in a residential area located in the immediate vicinity of construction sites. Since construction sites are often located at a short distance from existing residential buildings, it will be ineffective to install only a conventional noise barrier - walls. In this regard, we have developed a classification of shielding noise protection structures for construction sites, the complex application of which will make it possible to achieve standard noise levels in the adjacent residential area. The article presents the efficiency calculation and designs of two screens (perimeter and intra-sectoral) of five indicated in classification types.*

***Keywords:** words noise reduction, noise protection structure, residential buildings, perimeter screen, intra-sectoral screen*

***DOI:** 10.36336/akustika202139267*

1. INTRODUCTION

The relevance of the struggling against noise in construction in all its directions has been and remains undoubted. It has become especially aggravated in recent years due to a significant increase in the number of construction sites, especially in areas where new buildings are being built directly in the vicinity of an already inhabited houses.

According to the Department of Urban Development Policy of Moscow, in April 2020, 648.3 thousand square meters of real estate were commissioned. And in 4 months (January - April) 2020, 3.985 million square meters of real estate were commissioned [1]. The construction of new buildings and infrastructure facilities in large metropolitan areas is ongoing. Every year more and more new territories are being developed and built up.

To comply with the normative noise levels in residential buildings [2, 3], it is necessary to provide measures to reduce the noise level from construction sites. This article proposes designs of various types of temporary noise-protective shielding structures that will ensure the achievement of noise standards in the residential area.

Currently, for noise protection of adjacent residential buildings, various types of noise protection fencing are used. For our purposes, the main disadvantage of such structures is the "capitalism" of their installation (for example, on a strip foundation), which is not suitable for their temporary use and possible movement, considering the configuration of the construction site in the plan. The construction of new buildings often takes place in cramped conditions, where the construction of permanent noise barriers and other fences is impossible.

In this way it seems important to develop temporary, relatively lightweight and cheap mobile noise protection fences, allowing to achieve standard noise levels in the adjacent residential area.

2. CLASSIFICATION

Construction sites are currently use mainly security (not noise-proof) fences no more than 2 m high, which practically does not prevent the spread of noise to the nearest residential area. In this regard, we have developed a classification of noise protection screens that can be used in construction to effectively reduce the noise level. These fences include screens installed at the construction site itself, and screens on road construction machines (RCM) operating at construction sites, and screens that reduce noise levels directly in residential premises.

Screens intended for installation on the construction site, as well as the construction site perimeter fencing itself:

- perimeter noise screen - pre-fabricated screens - walls that are installed around the perimeter of the construction site. The height of these structures is 3-4 m. They consist of reflective - absorbing, reflective and combined panels;
- intra-sectoral screens - screens - walls provided for fencing the noisiest construction site (sector) within the site perimeter. These structures (in case of necessity) can be moved from one place to another, thereby increasing the level of efficiency of noise protection of the latter.

Screens installed on RCM:

- hinged - screens that are installed on the noisiest body of the RCM, including the worker, which will reduce the noise level at the source itself.
- Screens installed directly on a residential building:
- an overhead window noise protection screen (OWNPS) [9] - a sliding translucent screen installed from the outside into an existing window opening ("additional window"). Its device allows you to keep the existing windows and the structure of buildings intact, but at the same time allows you to further reduce the noise level in apartments without much effort when installing OWNPS;

- wall screens - a temporary translucent screen, which is mounted on the wall (facade) of a residential building from the side of the construction site at a distance of 1 m.

Allows to screen all window openings (or a necessary part of them) of the specified facade.

The types of shielding fences mentioned above will reduce the noise level from the construction site to standard values even with a small distance of residential buildings from the construction work place.

3. CONSTRUCTION OF THE PERIMETER SCREEN

Perimeter noise barriers are temporary fencing of the construction site, and in addition to reducing the noise level, they also perform security functions. These structures can consist of various types of panels (absorbent, absorbent-reflective). One of the main difficulties in the design of such screens is their fastening, since it is impractical and costly to arrange a pile or strip foundation for temporary structures. Another feature of perimeter screen is ease of assembly with minimal time investment.

One of the structures of the perimeter screen can be a screen with a wall made of absorbent-reflecting sandwich panels (Fig. 1).

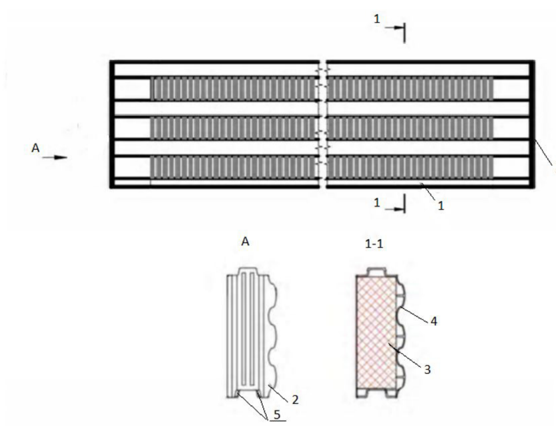

Fig. 1: Construction of absorbent-reflective sandwich panel: 1 - panel body; 2 - end cap; 3 - noise-absorbing filler; 4 - fiberglass; 5 – water drainage holes

Acoustic panels have small overall dimensions with height of 250 mm and 100 mm thickness, which simplifies their transportation and storage. Also, the advantage of these sandwich panels is their low weight, which does not exceed 15 kg.

The body of the protective panel is made of fiberglass. This material has a low specific weight and at the same time has high strength and rigidity [4]. Another advantage of the fiberglass panel is the absence of corrosion and resistance to anti--icing chemicals. The front panel consists of alternating horizontal radius or arcuate protrusions and valleys, which provide fast attenuation of reflected sound waves. Also, horizontal stiffeners can be made on the inner side of the body in the region of the projections to increase the strength characteristics.

The sound-absorbing filler is made of moisture resistant mineral wool. For additional protection against moisture and ensuring a long service life, the filler is protected by a layer of glass cloth impregnated with a sizing compound (emulsion or suspension based on polymer components, film-forming, antistatic and bonding agents that help protect the carbon fiber).

The end cap is made from a compound (thermoplastic polymer resin, cure in vivo and elastomeric materials). The cover fits snugly against the soundproofing panels and walls, without creating gaps for noise penetration. Also, the cover design provides recesses and holes for moisture drainage.

The noise protection panels described above are installed between I-beams that form an acoustic shield. The racks, in turn, are attached to the supports with four anchor bolts. The horizontal profile is a cold-rolled channel in which the panels are installed. It is the supporting element (frame) of the screen curtain and transfers the wind load from the panels to the posts.

The design of supports for attaching I-beams is shown in Fig. 2.

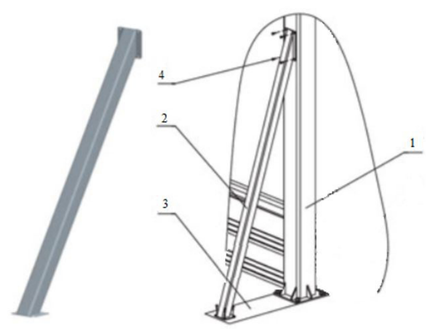

Fig. 2: Fastening the noise shield: 1 is I-beam, 2 is brace, 3 is support frame, 4 is the fastening of brace to the I-beam

The steel support (brace) is installed at an angle of 30 to 50 degrees and fixed to the support frame (channel) and the I-beam on the fixing bolts. The brace serves to give stability and rigidity to the structure. An example of such an attachment is shown in Fig. 3.

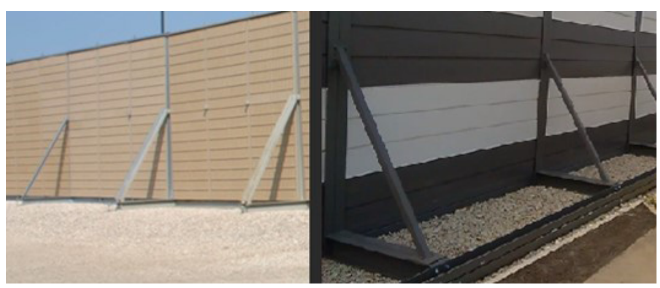

Fig. 3: An example of fastening a soundproof structure

For better stability of the perimeter noise shield, each post is additionally attached to the surface using a screw ground fastening (anchor), shown in Fig. 4.

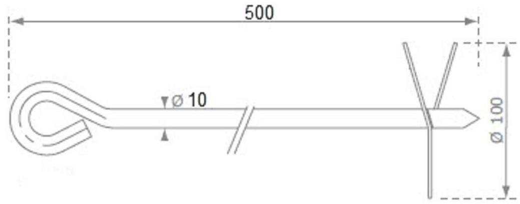

Fig. 4: Design of an anchor

The anchor is made of galvanized steel with a total length of 500 mm. The advantage of such a fastening is not only a guarantee of reliable fastening of the structure and reusable use, but also saving time and material when erecting the screen. A disc with sharp edges (100 mm diameter) can be easily screwed into the ground without the use of additional equipment.

The design of the perimeter screen described above ensures its reusability at various construction sites.

4. CONSTRUCTION OF THE INTRA-SECTORAL SCREEN

Noise during the construction of a building complex is very often local (point) in nature. Such sources of noise include pumps, compressors, various crushing plants, machines for preparing and distributing mixtures, diesel hammers, vibrators, and others.

Intra-sector noise protection screens are installed in the immediate vicinity of the noisiest area (sector) of work, i.e. in the area of direct sound. These structures are distinguished by both small overall dimensions (height no more than 3m) and relatively low weight, which allows them to be moved relatively easily and without the use of additional equipment throughout the entire area of the construction site.

The specified screen is a supporting frame made of aluminum, in which reflective - absorbing panels are installed. The design of the screen panels is shown in Fig. 5.

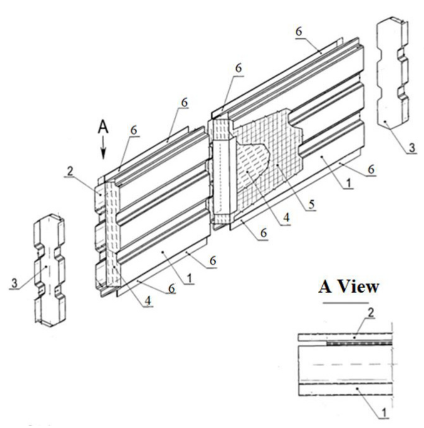

Fig. 5: Construction of the noise absorbing panel: 1 and 2 are front and rear covers; 3 is an end cap; 4 is sound-absorbing material; 5 is protective sound-transparent film; 6 are holes for attaching the covers to each other

Sound-absorbing panels are made of aluminum alloys or fiberglass and consist of flat sheets of the same shape with longitudinal trapezoidal stiffeners. The front cover, and if necessary the back cover, are made with perforations in the form of holes or in the form of louvers, which are necessary for the free penetration of sound waves through the holes. The perforation of the back cover will additionally absorb sound waves from construction machines and mechanisms, and not reflect them towards residential buildings. Also, the advantage of perforated panels is the increased resistance to wind loads compared to a solid sheet, i.e. at the same time the windage decreases [5].

The sound-absorbing elements are made of super-thin basalt fiber or mineral wool, enclosed in a polyethylene sheath, which protects the material from getting wet and slipping into the lower part of the panel. If the thickness of the sound-absorbing material (SAM) is less than 70 mm, its density should be at least 90 kg/m^3, with a thickness of more than 70 mm, the density should be 65 kg/m^3.

Fig. 6 shows a diagram of the installation of panels on top of each other as part of a screen unit.

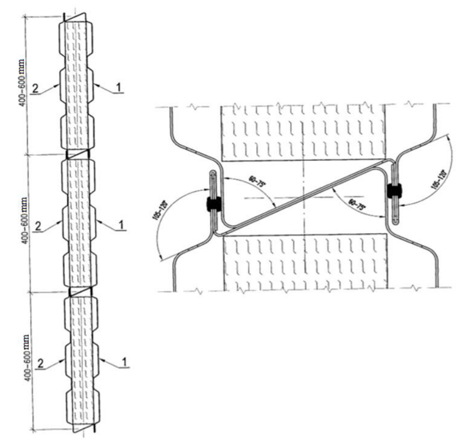

Fig. 6: Fastening the panels together: 1 and 2 are front and rear panel covers

The front and rear covers have a z-shaped mating surface in the upper and lower parts for secure fastening of the panels to each other. Each section of the intra-sectoral screen is assembled from panels 400/600 mm high and 3 m long. Such fastening gives the screen structure additional stability and reliable connection of the panels to each other.

On the lateral edges of the posts of the screen sections there are hinge elements for connecting the sections to each other. To increase noise insulation, an elastic sound-insulating seal is additionally installed behind the hinge elements. The design of the screen allows you to move it from place to place, as well as change its general configuration.

The general view of one section of the intra-sectoral screen is shown in Fig. 7.

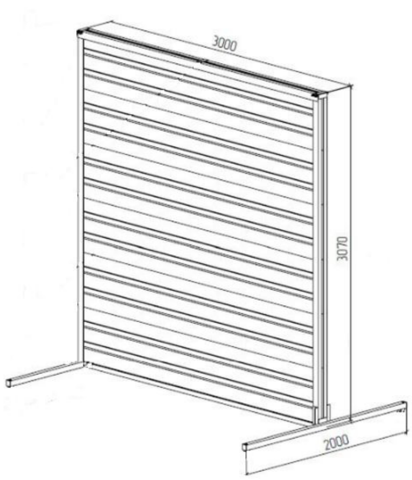

Fig. 7: General view of the section of the intra-sectoral screen

The design described above will reduce the noise level directly in the noisiest sector of the construction site.

5. EVALUATION OF NOISE PROTECTION SCREEN EFFICIENCY

We have carried out measurements of the noise levels of both six construction sites and the noise levels caused by them at the calculated points (CP) of the adjacent residential buildings in 2019 - 2020. These construction sites were located in the Central, North, North-West and South-West administrative districts of the Moscow city.

To assess the efficiency of noise protection (***ΔLscr***) of the proposed intrasectoral and perimeter screens, the methodological recommendations set forth in [6] were used, considering the approaches and refinements proposed in [7, 8]. Screens made of absorbent-reflective panels were chosen as a calculation object.

The calculation of $\boldsymbol{\Delta L_{scr}}$ was carried out according to the well-known formula:

$$\Delta \boldsymbol{L_{scr}} = \mathbf{18,2 + 7,8\,lg}(\boldsymbol{\delta} + \mathbf{0,02})\,, \boldsymbol{dBA} \quad (1)$$

In this case, the difference in the path of the sound beam δ was determined by the well-known expression:

$$\boldsymbol{\delta = a + b - c, m}, \quad (2)$$

where

a is the shortest distance from a noise source (construction machine, mechanism) to the upper edge of the screen, m;

b is the shortest distance from the upper edge of the screen to CP, m;

c is the shortest distance from noise source (NS) to CP, m.

When performing calculations, the position of the acoustic center of the NS was determined above the 1.00 m level.

Evaluation of the effectiveness of noise protection of the perimeter screen with a height of 4 m was carried out at different distances of the NS on the construction site from the screen. The real distances from the boundaries of six construction sites to the CP of residential buildings are taken from the data of the measurements. The calculation results are shown in Tab. 1.

Site number	CP	*ΔLscr*, dBA at a distance from NS to the screen, m					
		10	20	30	40	50	60
Construction sites 2019							
1	1	16,3	14,7	13,9	13,5	13,1	12,9
	2	16,4	14,8	14,0	13,6	13,3	13,0
	3	15,8	13,8	12,7	12,0	11,5	11,1
2	1	16,0	14,2	13,3	12,7	12,3	12,0
	2	15,9	14,1	13,1	12,5	12,0	11,7
	3	15,9	13,9	12,9	12,3	11,8	11,4
3	1	16,1	14,4	13,5	12,9	12,6	12,3
	2	16,0	14,2	13,3	12,7	12,3	12,0
	3	15,9	14,0	13,0	12,3	11,9	11,5
4	1	17,4	16,4	15,9	15,7	15,5	15,4
	2	16,2	14,5	13,7	13,2	12,8	12,5
	3	16,9	14,7	13,9	13,4	13,1	12,8
Construction sites 2020							
1	1	18,7	18,1	17,8	17,6	17,6	17,5
	2	16,2	14,5	13,7	13,2	12,9	12,6
	3	18,7	18,1	17,8	17,6	17,6	17,5
	4	15,6	13,6	12,5	11,8	11,3	11,0
2	1	16,2	14,6	13,7	13,2	12,9	12,7
	2	16,2	14,6	13,7	13,2	12,9	12,7

Tab. 1: The perimeter screen efficiency at different distances of the NS

From the presented data it can be seen that the efficiency of the perimeter screen 4 m high in the most "stressed" case (60 m) is 11,0 – 17,5 dBA.

Evaluation of the effectiveness of an intra-sectoral screen with a height of 3 m was carried out at its calculated distance from the NS of 3 m and at various distances of the screen to the boundaries of the construction site. The real distances from the boundaries of the construction site to the CP were also carried out according to the measurements taken. The calculation results are shown in Tab. 2.

Site number	CP	*ΔLscr*, dBA at a distance from NS to the screen, m					
		10	20	30	40	50	60
Construction sites 2019							
1	1	16,3	14,7	13,9	13,5	13,1	12,9
	2	16,4	14,8	14,0	13,6	13,3	13,0
	3	15,8	13,8	12,7	12,0	11,5	11,1
2	1	16,0	14,2	13,3	12,7	12,3	12,0
	2	15,9	14,1	13,1	12,5	12,0	11,7
	3	15,9	13,9	12,9	12,3	11,8	11,4
3	1	16,1	14,4	13,5	12,9	12,6	12,3
	2	16,0	14,2	13,3	12,7	12,3	12,0
	3	15,9	14,0	13,0	12,3	11,9	11,5
4	1	17,4	16,4	15,9	15,7	15,5	15,4
	2	16,2	14,5	13,7	13,2	12,8	12,5
	3	16,9	14,7	13,9	13,4	13,1	12,8
Construction sites 2020							
1	1	18,7	18,1	17,8	17,6	17,6	17,5
	2	16,2	14,5	13,7	13,2	12,9	12,6
	3	18,7	18,1	17,8	17,6	17,6	17,5
	4	15,6	13,6	12,5	11,8	11,3	11,0
2	1	16,2	14,6	13,7	13,2	12,9	12,7
	2	16,2	14,6	13,7	13,2	12,9	12,7

Tab. 2: An intra-sectoral screen efficiency

It follows from the calculations that the efficiency of the intra-sectoral screen is insignificantly dependent on the distance between the latter and the border of the construction site and reaches 16,7 dBA.

6. CONCLUSION

In this case the use of the perimeter and intra-sector screens proposed in the article will significantly reduce the noise level of construction sites affecting the adjacent residential buildings.

It can be also recommended to carry out the noisiest construction works during the daytime (7.00 a.m. - 11.00 p.m.).

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