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TECNIQUE FOR ESTIMATING THE EFFICIENCY OF NOISE PROTECTIVE ACOUSTIC SCREENS IN THE PRESENCE OF FLAT ANTI-DIFFRACTORS

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***Abstract**: To increase the efficiency of acoustic screens when protecting against acoustic noise, anti-diffractors are used to reduce the diffraction level on the upper edge of the screen. The aim of the work is to refine the mathematical model used to assess noise protection efficiency with the help of an acoustic screen with an installed one-sided flat-type anti-diffractor. The well-known techniques based on the principle of the amplitude dependence of the sound wave intensity from two sources are analyzed: a point-type noise source and a secondary cylindrical wave source - the screen edge, on which the sound wave is diffracted.*

Taking into account that the change in the distance between the anti-diffractor and the working point in the acoustic shadow zone is associated with a change in the diffraction angle, it is proposed to evaluate the acoustic screen effectiveness by comparing the initial sound wave propagation paths. An approach to a mathematical calculation model formation is proposed, in which the diffraction point located at the intersection of two components of the wave path to the operating point is considered to be the location of the sound wave secondary source in the area of the screen upper edge: from the noise source to the flat-type anti-diffractor installed on the upper edge of the screen, and from the anti-diffractor rear edge to the operating point. Relationships that make it possible to solve the problem of analytical assessment of noise-protective acoustic screens' effectiveness when installing anti-diffractors on their upper face in the form of flat hinged panels oriented towards the acoustic shadow are obtained.

***Keywords:** acoustic wave, noise protection acoustic screen, diffraction, anti-diffractor, acoustic screen efficiency*

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1. INTRODUCTION

Acoustic noise is becoming one of the most significant problems in the modern technosphere. Industrial production, the implementation of repair or construction work, an increase in the number of vehicles, including railway, and the intensification of traffic flows - all these lead to the fact that the increase in noise level becomes constant and reaches 0.5 dB per year.
To combat noise penetrating residential areas, a variety of means are used, ranging from requirements to reduce the noise level at the source itself and ending with the removal of this source at a safe distance. One of such widespread means is an acoustic screen (AS), which is an obstacle to noise propagation and makes it possible to significantly reduce sound pressure level (SPL) at a specific point in the urban environment.

The use of AS is widely practiced in different countries [1,2,3,4]. The principle of its application is simple and considered in detail in a number of works, for example, in [5,6,7] and others. But with all the advantages, acoustic screens are not without drawbacks from the point of view of their application in urban development, for example, due to their overall dimensions, since in many cases, to increase the screen efficiency and reduce the SPL in the acoustic shadow zone, an increase in its overall dimensions is required, for example - height [8] (a noise protection 300 mm high screen, designed to reduce railway transport noise in an urban environment can be a rare exception to this rule [9]. But this height is determined, first of all, by the peculiarities of the railway track layout in an urban environment). However, a strong (over 6 m) increase in the height of the screen is not always possible due to a number of reasons, among which we can note both purely constructive and aesthetic ones. So, for a high AS, it is necessary to develop a more powerful foundation and reinforced supporting structures, from an aesthetic point of view, the integrity of the architectural and planning solution of the urban environment territory is violated.

To increase protection efficiency, additional elements that reduce the diffraction level at the upper edge of the screen - anti-diffractors (AD) or hinged elements made both in the form of one-sided or double-sided shelves (canopies) and in the form of an extended sound-absorbing structure are used. Such add-ons make it possible to increase the AS efficiency by 3-6 dB [10].

2. PROBLEM STATEMENT

The article discusses the methodological principles for assessing the effectiveness of reducing the noise level in the acoustic shadow zone when using an acoustic screen with an AD (hinged elements) in the form of a one-sided shelf (L-shaped visor), inclined towards the acoustic shadow zone [11].

At present, the calculations of acoustic screens are based on the works of the Japanese researcher Z. Maekawa [12, 13], who applied the ideas of the diffraction theory to screens of various shapes. The simple relation proposed by Z. Maekava for calculating semi-infinite screens located in free space with an undirected sound source is based on taking into account the Fresnel number N and the distance between the noise source (NS) and the AS upper edge - A; calculated point (CP) and the AS upper edge - B; between NS and CP- d [12]:

$$\Delta L = 10lg(20N), \text{ dB} \tag{1}$$

where

$N = \frac{2\delta}{\lambda}$;

δ - wave path difference (δ =A+ B - d)

λ - sound wavelength.

The calculation method proposed by Z. Maekava is widely used to assess the AS efficiency installed in free space (at small diffraction angles). Based on this approach, a number of methods for analyzing acoustic screens have been developed.
This article discusses the case of AS installation in the form of a one-sided canopy facing the acoustic shadow. The aim of the work is to refine the mathematical model used to assess the effectiveness of an acoustic screen noise protection with an installed one-sided flat-type anti-diffractor.
The article is a continuation of the previously performed work on the analysis of the noise-absorbing capabilities of noise-protective acoustic screens [2,11,14].

3. GENERAL PROVISIONS

3.1.Analysis of an acoustic wave energy behind an acoustic screen without an anti-diffractor

In the subsequent considerations, we will rely on the approach outlined in [1,5,10,15,16].

Considering the energy characteristics of the sound signal incident on the AS, we will proceed from the assumptions that (fig. 1): a) the sound wave 1 falls on the AS front surface; b) as the AS height increases, the sound intensity decreases uniformly; c) the supporting surface between the NS and the AS has sound-absorbing properties; d) on the AS upper edge, the acoustic wave 2 diffracts, partially scattered, partially passing into the acoustic shadow zone 3.

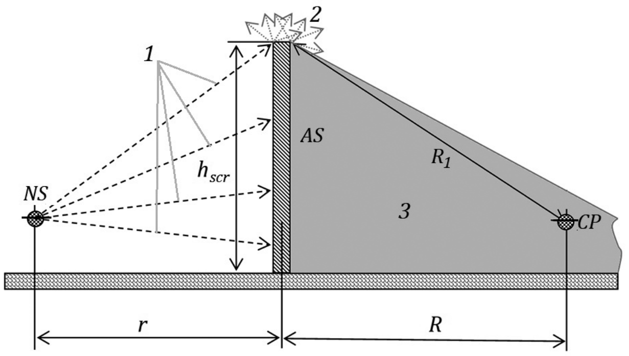

Fig.1: Acoustic screen diagram for point NS

Taking these assumptions into account, the intensity of the sound incident on the AS is calculated as follows:

$$I_{inc} = \frac{W_s(1-\alpha_{sur})}{2\pi r^2}, \text{ W/m}^2 \tag{2}$$

where

α_{sur} - supporting surface sound absorption coefficient

r - distance from NS to AS, m

W_s - acoustic power of a point noise source, W.

Assuming that the acoustic signal is emitted by a conventional 1 m wide band, the acoustic power of the sound signal incident on the AS is calculated by the formula:

$$W_{inc} = I_{inc} \cdot 1 \cdot l_{scr}, \text{ W} \tag{3}$$

where

l_{scr} – AS length, m

1 – emission bandwidth, m.

When determining the intensity of the sound wave on the AS upper free edge, in addition to the assumption of sound intensity decrease at a given point relative to the AS lower part, we will also proceed from the assumption that the sound is emitted by a linear source with a length l_{scr}. Then the value of the sound intensity on the upper free edge of the AE is determined by the ratio:

$$I_p = \frac{W_{inc}(1-\alpha_{scr})}{\pi l_{scr} h_{scr}} arctg \frac{l_{scr}}{2h_{scr}} \tag{4}$$

where

h_{scr} – AS height, m;

α_{scr} – frequency-dependent sound absorption coefficient of acoustic panels that make up the AS.

When analyzing the propagation of a point source signal, we take into account that diffraction takes place on the upper free edge, as a result of which the AS upper free edge is a secondary linear type radiator. Acoustic power radiated by such a conventional linear radiator is determined by the following relationship:

$$W_p = I_p l_{scr} \lambda \beta_{dif} \tag{5}$$

where

β_{dif} – diffraction coefficient, determined by the ratio of the intensity of the sound diffracted by the AS to the incident sound intensity;

λ – sound wave length, m.

The sound intensity of in the CP in the AS presence is determined as follows:

$$I_{CP}^{AS} = \frac{W_p}{2\pi l_{scr} R} arctg \frac{l_{scr}}{2R} \tag{6}$$

where

R – distance from AS to CP.

Taking into account (2) - (5) on the basis of (6), after carrying out the necessary transformations, a relation for assessing the acoustic efficiency of a reflective-absorbing AS for a point NS [10, 16] can be obtained:

$$\Delta L_{scr} = 10lg\frac{r^2R}{(R+r)^2r_0} + 10lg\frac{h_{scr}}{\lambda} + 10lg\frac{1}{\beta_{scr}} - 10lg(1-\alpha_{sur}) - 10lg(1-\alpha_{scr}) - 10lg\, arctg\frac{l_{scr}}{2h_{scr}} - 10lg\, arctg\frac{l_{scr}}{2R} + 10lg2\pi^2, \text{dB} \quad (7)$$

3.2.Analysis of an acoustic wave energy behind an acoustic screen with hinged elements

If there is a canopy on the AS upper face in the form of a flat shelf (Fig. 2) and a conditional NS 1 m wide, the intensity of the sound incident on the AS is determined as

$$I_{inc} = \frac{W_s}{2\pi r^2}, \quad (8)$$

and the acoustic power at the bottom of the screen is determined by the formula (3):

$$W_{inc} = I_{inc} \cdot 1 \cdot l_{scr}$$

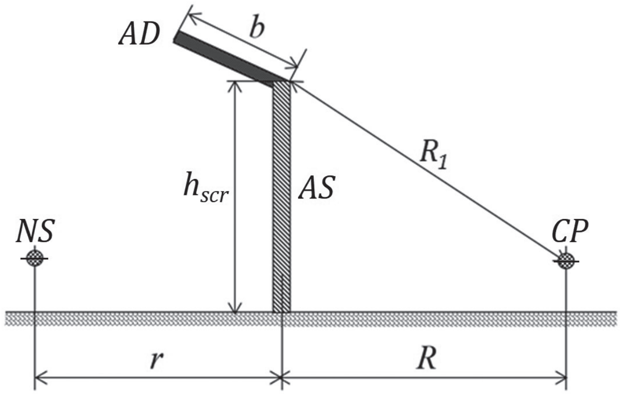

Fig.2: AS scheme with a flat hinged element

Sound intensity in front of the hinged element

$$I_{upp} = \frac{W_{inc}(1-\alpha_{scr})}{\frac{\pi}{2}h_{scr}l_{scr}} arctg\frac{l_{scr}}{2h_{scr}} \quad (9)$$

where

h_{scr} - AS height to the hinged element (anti-diffractor), m.

Then the acoustic power at the AS top

$$W_{upp} = I_{upp}l_{scr}\lambda \quad (10)$$

and the sound intensity on the free edge of the AS

$$I_{\mathrm{p}} = \frac{W_{upp}(1-\propto_{AD})}{\frac{\pi}{2}bl_{scr}} arctg\frac{l_{scr}}{2b} \quad (11)$$

where

b – hinged element shelf width (anti-diffractor), m;

$\propto_{AD}$ – anti-diffractor sound absorption coefficient.

Based on this, the acoustic power at the AD free edge is determined by the ratio:

$$W_p = I_pl_{scr}\lambda\beta_{dif} \quad (12)$$

where

β_{dif} – diffraction coefficient at the free edge of the hinged element

Sound intensity in CP in the presence of AS

$$I_{CP}^{\mathrm{AD}} = \frac{W_p}{\pi l_{scr}R_1} arctg\frac{l_{scr}}{2R_1} \quad (13)$$

where

R_1 – distance between AD and CP, m.

Substituting (9) - (12) into (13), we obtain

$$I_{CP}^{\mathrm{AD}} = \frac{4W_sl_{scr}(1-\alpha_{scr})l_{scr}\lambda l_{scr}\lambda(1-\propto_{\mathrm{AD}})\beta_{dif}}{2\pi r^2\pi h_{scr}l_{scr}\pi bl_{scr}\pi l_{scr}R_1} arctg\frac{l_{scr}}{2h_{scr}} arctg\frac{l_{scr}}{2b_{\mathrm{p}}} arctg\frac{l_{scr}}{2R_1} \quad (14)$$

and the general AS efficiency assessment of the an AS with a hinged element is

$$\Delta L = 10lg\frac{W_S2\pi r^2l_{scr}\pi h_{scr}\pi b\pi R_1}{W_S2\pi(r+R)^2(1-\alpha_{scr})(1-\alpha_{\mathrm{AD}})\lambda\lambda\beta_{dif}arctg\frac{l_{scr}}{2h_{scr}}arctg\frac{l_{scr}}{2b}arctg\frac{l_{scr}}{2R_1}} \quad (15)$$

After carrying out the necessary transformations, the ratio for assessing the acoustic efficiency of an AS with a flat-type AD takes on a complete form [10, 16]

$$\Delta L_{scr} = 10lg\frac{r^2R_1}{(R+r)^2r_0} + 10lg\frac{h_{scr}}{\lambda} + 10lg\frac{b}{\lambda} + 10lg\frac{1}{\beta_{dif}} - 10lg(1-\alpha_{scr}) - 10lg(1-\alpha_{\mathrm{AD}}) - 10lg\, arctg\frac{l_{scr}}{2h_{scr}} - 10lg\, arctg\frac{l_{scr}}{2b} - 10lg\, arctg\frac{l_{scr}}{2R_1} + 10lg\pi^3 - 6, \text{dB}, \quad (16)$$

where

r_0 - 1 m.

4. ASSESSMENT OF THE SCREEN EFFICIENCY AT L-SHAPED AD

In the above technique, the expression for assessing the acoustic screen effectiveness (16) is based on the principle of comparing the amplitude dependences of the intensity of the sound wave generated by two sources: a point source in free space and a secondary source of a cylindrical wave - the edge of the screen, or two additional linear sources - the edge of the screen and canopy. This analytical approach shows a weak dependence on the distance between the CP and the screen. It should also be taken into account that a change in the distance between the edge of the superstructure (anti-diffractor) and CP is associated with a change in the diffraction angle, and, as a consequence, with a change in the diffraction coefficient.

Therefore, it is proposed to consider this dependence by analogy with the method of Z. Maekawa through a comparison of the propagation paths of the original sound wave. For this purpose, it is assumed that the wave path to the calculation point consists of two sections (Fig. 3) - AF (NS - diffraction point) and FC (diffraction point - CP), and the point of their intersection F (diffraction point) is the location of the secondary the sound wave source.

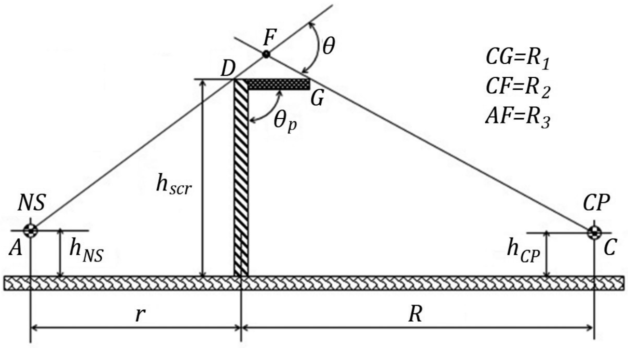

Fig.3: Scheme with a horizontal hinged element

For three options of hinged elements (Fig. 3, Fig. 4, Fig. 5), the distance R_1 and the diffraction angle θ are determined as follows:

a) with a horizontal hinged element (Fig.3):

$$R_1 = \sqrt{(R-b)^2 + (h_{scr} - h_{CP})^2}\text{, m} \tag{17}$$

$$\theta = arctg\,\frac{h_{scr}-h_{CP}}{R-b} + arctg\,\frac{h_{scr}-h_{\mathrm{NS}}}{r} \tag{18}$$

where

h_{CP} - height of the working point above the ground, m;

h_{NS} - height of the noise source above the ground, m.

b) with a hinged element at an acute angle to the AS (Fig. 4):

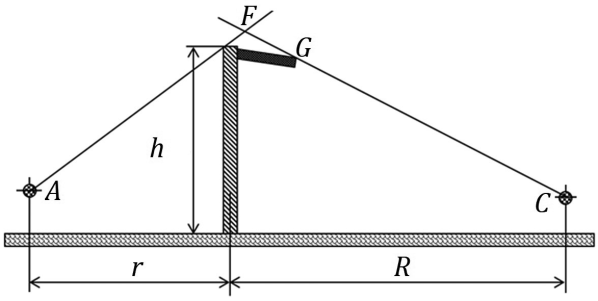

Fig.4: Scheme with a hinged element at an acute angle to the screen

$$R_1 = \sqrt{\left(\frac{R-b}{sin\,\theta_{\mathrm{p}}}\right)^2 + \left(\frac{h_{scr}-h_{CP}-b}{cos\,\theta_p}\right)^2} \tag{19}$$

$$\theta = arctg\,\frac{h_{scr}-h_{CP}-bcos\,\theta_{\mathrm{p}}}{R-bsin\,\theta_p} + arctg\,\frac{h_{scr}-h_{\mathrm{NS}}}{r} \tag{20}$$

c) with a hinged element at an obtuse angle to the screen (Fig. 5):

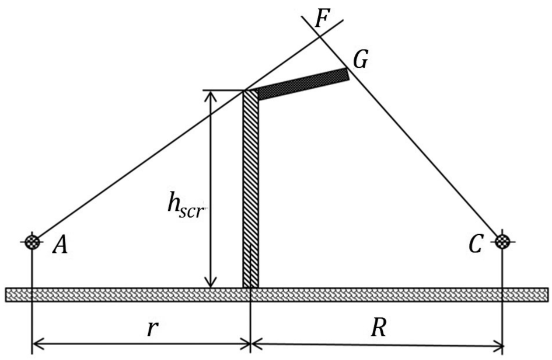

Fig.5: Scheme with a hinged element at an obtuse angle to the screen

$$R_1 = \sqrt{\left(R - \frac{b}{\cos\left(\theta_p-\frac{\pi}{2}\right)}\right)^2 + \left(h_{scr} - h_{CP} - \frac{b}{sin\left(\theta_p-\frac{\pi}{2}\right)}\right)^2} \tag{21}$$

$$\theta = arctg\,\frac{h_{scr}-h_{CP}+b\cos\,(\pi-\theta_p)}{R-b\sin\,(\pi-\theta_p)} + arctg\,\frac{h_{scr}-h_{\mathrm{NS}}}{r} \tag{22}$$

The rest of the components are determined by means of simple geometric constructions and include: R_2 - the distance between CP and the point of diffraction on the beam (point F); R_3 - the distance between the NS and the point of diffraction on the beam; θ - the inclination angle of the AD panel relative to the AS.

4.1. Efficiency of AS with AD for the case of a point source of noise

With a point source of noise (taking into account the above considered constructions), the efficiency of an AS with a hinged element for an AD panel type, oriented in the direction of the acoustic shadow zone, is equal to

$$\Delta L_{scr} = 10\lg\frac{(r^2+R)^2}{(R_3+R_2)^2} + 10\lg\frac{h_{scr}}{\lambda} + 10\lg\frac{b}{\lambda} + 10\lg\frac{1}{\beta} - 10\lg(1-\alpha_{scr}) - 10\lg(1-\alpha_{\mathrm{AD}}) - 10\lg arctg\,\frac{l_{scr}}{2h_{scr}} - 10\lg arctg\,\frac{l_{scr}}{2b} - 10\lg arctg\,\frac{l_{scr}}{2R_1} + 10\lg\pi^3 - 6,\ \text{dB.} \tag{23}$$

4.2. Efficiency of AS with AD for the case of a linear noise source

With a linear source of sound intensity incident on the screen is:

$$I_{\mathrm{inc}} = \frac{W_{\mathrm{s}}}{2\pi r l_{scr}}\,arctg\,\frac{l_{scr}}{2r} \tag{24}$$

and the sound intensity in the CP without AS is equal to:

$$I_{\mathrm{CP}} = \frac{W_{\,s}}{2\pi(r+R)l_{scr}}\,arctg\,\frac{l_{scr}}{2(r+R)}. \tag{25}$$

The sound intensity at the AS diffraction edge is calculated similarly to (4), (6):

$$I_{dif} = \frac{W_{upp}(1-\alpha_{\mathrm{AD}})}{\frac{\pi}{2}h_{scr}l_{scr}}\,arctg\,\frac{l_{scr}}{2h_{scr}} \tag{26}$$

The source length is taken to be equal to the AS length. Then the screen efficiency is equal to:

$$\Delta L_{\mathrm{scr}} = 10\lg\frac{rR_1}{R_3+R_2} + 10\lg arctg\,\frac{l_{\mathrm{scr}}}{2r} - 10\lg arctg\,\frac{l_{\mathrm{scr}}}{2(r+R)} + 10lg\,\frac{h_{\mathrm{scr}}}{\lambda} + 10\lg\frac{b}{\lambda} + 10\lg\frac{1}{\beta} - 10\lg(1-\alpha_{\mathrm{scr}}) - 10lg\left(1-\alpha_{\text{АД}}\right) - 10lg\,arctg\,\frac{l_{\mathrm{scr}}}{2h_{\mathrm{scr}}} - 10\lg arctg\,\frac{l_{\mathrm{scr}}}{2b} - 10\lg arctg\,\frac{l_{\mathrm{scr}}}{2R_1} + 10\lg\pi^3 - 3,\ \text{dB} \tag{27}$$

4.3.Efficiency of AS with AD for the case of a plane noise

For a plane noise source, the intensity of a sound wave incident on the screen is:

$$I_{\mathrm{inc}} = \frac{W_s}{\pi h_{\mathrm{NS}}l_{scr}}\,arctg\,\frac{h_{NS}l_{scr}}{2r\sqrt{4r^2+(h_{NS})^2+{l_{scr}}^2}} \tag{28}$$

and the sound intensity in the OP without AS is equal to:

$$I_{CP} = \frac{W_s}{\pi k h_{scr}l_{scr}}\,arctg\,\frac{kh_{scr}l_{scr}}{2r\sqrt{4(r+R)^2+(kh_{scr})^2+{l_{scr}}^2}} \tag{29}$$

where

k – coefficient describing the influence of the near sound field depending on the noise source size.

The intensity of the sound wave arriving at the CP from the diffraction point F (fig. 3):

$$I_{CP}^{dif} = \frac{W_S}{\pi k h_{scr} l_{scr}} arctg \frac{k h_{scr} l_{scr}}{2(R_2-R_1)\sqrt{4R_2^2+(kh\,scr\quad)^2+l_{scr}{}^2}} \qquad (30)$$

Then the overall assessment of the AS efficiency will be obtained in the form:

$$\Delta L = 10lg \frac{W_S \pi h_{NS} l_{scr} arctg \frac{h_{NS} l_{scr}}{2(r+R)\sqrt{4(r+R)^2+(h_{scr})^2+l_{scr}{}^2}} \pi h_{scr} \pi b \pi R_1}{W_S \pi h_{NS} l_{scr} arctg \frac{h_{NS} l_{scr}}{2(R_2-R_1)\sqrt{4R_2^2+(h_{NS})^2+l_{scr}{}^2}} (1-\alpha_{scr})(1-\alpha_p)\lambda\lambda\beta_{dif} arctg \frac{l_{scr}}{2h_{scr}} arctg \frac{l_{scr}}{2b} arctg \frac{l_{scr}}{2R_1}} \qquad (31)$$

After carrying out the necessary transformations, we obtain the ratio for assessing the AS acoustic efficiency in the case of a flat noise source:)

$$\Delta L_{scr} = 10lg \frac{h_{NS}}{kh_{scr}} + 10\lg arctg \frac{k h_{NS} l_{scr}}{2(r+R)\sqrt{4(r+R)^2+(kh_{scr})^2+l_{scr}{}^2}} - 10\lg arctg \frac{h_{NS} l_{scr}}{2(R_2-R_1)\sqrt{4R_2^2+(h_{NS})^2+l_{scr}{}^2}} + 10lg \frac{h_{scr}}{\lambda} + 10\lg\frac{b}{\lambda} + 10\lg\frac{1}{\beta} - 10\lg(1-\alpha_{scr}) - 10lg(1-\alpha_p) - 10lg\, arctg \frac{l_{scr}}{2h_{scr}} - 10\lg arctg \frac{l_{scr}}{2b} - 10\lg arctg \frac{l_{scr}}{2R_1} + 10\lg \pi^3, \text{ dB} \qquad (32)$$

5. SOME RESULTS

As it has been already noted, the ratios proposed for the calculation take into account acoustic signal propagation along two sections: the initial acoustic signal along the AF line and the secondary signal along the FC line. This approach makes it possible to better take into account the dependence of the AS efficiency estimation on the distance and diffraction angle, and, consequently, on the diffraction coefficient change.

As it can be seen from Fig. 3, when the r and R values change, the diffraction point location (point F), which is the secondary radiation point, changes as well. This change is taken into account by controlling the $\boldsymbol{R_1}$, $\boldsymbol{R_2}$ and $\boldsymbol{R_3}$ distances.

Verification of the relations proposed for assessing the effectiveness of AS ratios should be carried out by comparing the calculated results with experimental data. The organization of such tests is a rather difficult task that goes beyond this paper scope. However, within the framework of the article, we can carry out model calculations that allow us to characterize some of the indicators considered in the proposed methodology.

The calculation results are presented in Tab. 1. Two cases of the ***NS*** location relative to the ***AS*** are considered: $\boldsymbol{r}$ = 3 m and $\boldsymbol{r}$ = 7 m. When calculating, it was assumed that: $\boldsymbol{h_{OP}} = \boldsymbol{h_{NS}}$ = 1 м; $\boldsymbol{h_{SCR}}$ = 3 m; $\boldsymbol{b}$ = 0,6 m. In addition to the $\boldsymbol{R_1}$, $\boldsymbol{R_2}$, $\boldsymbol{R_3}$ and $\boldsymbol{\theta}$ values, Tab. 1 also shows the diffraction index values ***10lg1/β*** for each $\boldsymbol{\theta}$ value.

r, m	R, m	R_1, m	R_2, m	R_3, m	θ, degree	$10\,lg\,1/\beta$
3	1.5	2.26	2.53	4.19	110,5	5
	3	3.18	3.45	4.07	84,685	5
	5	4.87	5.18	3.98	69,387	5
	7.5	7.21	7.55	3.92	61,136	5
	10	9.63	9.99	3.89	56,953	6
	15	14.55	14.95	3.85	52,885	6
	20	19.52	19.93	3.83	50,880	6
7	1.5	2.27	2.36	7.86	88,696	5
	3	3.18	3.28	7.82	62,855	5
	5	4.87	5.0	7.77	47,556	6
	7.5	7.21	7.37	7.74	39,306	7
	10	9.63	9.81	7.71	35,180	7
	15	14.55	14.77	7.68	31,055	8
	20	19.52	19.74	7.66	29,049	8

Table 1: Simulation results

The calculation results seem to be correct, however, of course, they cannot confirm or refute the assumption about the proposed method applicability for assessing the effectiveness of acoustic screens with a hinged-type anti-diffractor, oriented towards the acoustic shadow.

6. CONCLUSION

The completed theoretical constructions based on the method of calculating screens of various shapes proposed by Z. Maekava and developed by N.I. Ivanov, N.V. Tyurina and other researchers, made it possible to obtain relationships that take into account the features of diffraction of acoustic waves on the acoustic screen upper edge. These ratios make it possible to solve the problem of analytical assessment of the effectiveness of noise-protective acoustic screens when installing anti-diffractors on their upper edge in the form of flat hinged panels oriented towards the acoustic shadow.

An approach to the formation of a mathematical calculation model in which the diffraction point located at the intersection of two components of the wave path to the operating point is considered to be the location of the secondary source of the sound wave in the area of the screen upper edge: from the noise source to the flat-type anti-diffractor installed on the upper edge of the screen, and from the rear edge of the anti--diffractor to the operating point is proposed.

Analytical evaluation of the effectiveness of noise protection screens with flat anti-diffractors of the L-shaped type, obtained in this work, require verification, which consists in comparison with the experimental results of field studies at test sites.

The issue of the effect of the screen sound absorption coefficients ($\boldsymbol{\alpha_{scr}}$) and the mounted anti-diffractor ($\propto_{AD}$)on the AS efficiency is also significant for the study. In the proposed models, their influence can be significant.

These coefficients are determined by the AS and AD construction types. Rejection of the simplest AS variants made of reinforced concrete slabs [17], which are quite common in some countries, and the transition to the use of complex porous structures, including edge [18] or internal hollow resonator elements in the form of Helmholtz resonators [2,11,19], half-wave and quarter-wave resonators [20], will make it possible to change noise absorption properties in a wide range and design the constituent screen elements with the required absorption characteristics.

The study of this issue should also be considered important in future research.

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