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ATTENUATION OF THE ACOUSTIC SCREENS IN CLOSED SPACES

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Lucrarea prezintă calculul atenuării acustice a unui ecran semi-infinit, plasat într-un spațiu liber sau semireverberant, luând în considerare teoria aproximativă a lui Sabine şi unele rezultate privind studiul difracției acustice prin metoda potențialului acustic. Au fost efectuate calcule numerice privind atenuarea ecranelor în câmp semireverberant pentru variația parametrilor geometrici ai poziției ecranului şi a caracteristicilor acustice ale camerei. De asemenea au fost prezentate rezultate experimentale care au fost comparate cu cele teoretice.

The paper presents the calculation of the acoustic attenuation of a semi-infinite screen, placed in a semi-reverberant space. Sabine's approximate theory and several results regarding the study of acoustic diffraction obtained by the method of the acoustic potential were taken into consideration. Numerical calculations regarding the attenuation of screens in a semi-reverberant field taking into account the variation of the geometrical parameters of the position of the screen and of the acoustic characteristics of the room have been performed. Experimental results have been presented and compared to the theoretical ones..

1. Introduction

The study of the attenuation produced by an acoustic screen is normally performed in a free field, taking into account the diffraction of the direct wave at the edge of the screen and some corrections due to the temperature, to the influence of the soil absorption and to the wind gradient etc.

In closed spaces the calculated attenuation in the presence of an acoustic screen requires corrections of the calculation relations presented in the classical theory [1,2]. These are due to the presence of the reverberant field.

The present paper presents the calculation of the attenuation of a semi-infinite screen, taking into consideration Sabine's approximate theory and some of Stan's results [3] regarding the study of acoustic diffraction by the method of the acoustic potential.

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2. Theoretical modelling of an acoustic screen in a closed space

We denote by L_{po} the rms acoustic pressure level produced by a source having the level of acoustic power L_{Π}. In an observation point (O) placed at a distance r from the source (S) its expression will be [2]:

$$L_{po} = L_{\Pi} + 10\lg\left(\frac{Q}{4\pi r^2} + \frac{4}{R}\right) \quad (1)$$

where Q is the directivity of the source of noise while R is the absorption constant of the room.

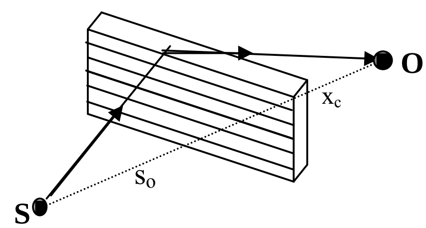

Fig.1.

If a screen is placed between the source (S) and the observer (O), the square acoustic pressure p^2 at the receiver's position will be the sum of the square of the pressure due to the diffracted field around the screen p_d^2 and the square of the pressure of the reverberant field p_r^2, that is:

$$p^2 = p_d^2 + p_r^2 \quad (2)$$

The level corresponding to the acoustic pressure will be:

$$L_p = L_d + L_r \quad (3)$$

The acoustic attenuation introduced by the screen in the closed space is [4]:

$$\Delta L = L_o - L_p = 10\lg\left(\frac{p_o^2}{p^2}\right) \quad (4)$$

where L_o is the level of the acoustic pressure in the absence of the screen.

The screen performance depends on the diffraction of the acoustic waves at the edge of the screen. The Fresnel diffraction method or the method of the acoustic potential are used to study the acoustic diffraction. According to the method of the acoustic potential the attenuation caused by a screen in a free space is expressed as follows:

$$\Delta L_{fs} = -6 + 10\lg N_I^2 \tag{5}$$

where

$$N_I^2 = \left[C(u)^2 + S(u)^2\right]^2 \cdot \left[C(v)^2 + S(u)^2\right]^2 \tag{6}$$

are groups of Bessel functions [3] depending on the parameters u and v, which have the following expressions:

$$u = a\sqrt{\frac{2}{\lambda}\cdot\frac{1}{x_r}}\,; \quad v = b\sqrt{\frac{2}{\lambda}\cdot\frac{1}{x_r}} \tag{7}$$

where

x_r is the reduced distance defined by the relation

$$\frac{1}{x_r} = \frac{1}{x_o} + \frac{1}{s_o}\,; \tag{8}$$

$SO = x_o + s_o$ is the distance between the source and the observer (fig.1);

a, b are the sizes of the panel.

The acoustic attentuation of the noise produced by a screen in a closed space, in the observation point behind the screen, is defined by the relation:

$$\Delta L_{cs} = 10\lg\frac{I_d + I_{rev}}{I_{dif} + I_{rev}} \qquad \text{(dB)} \tag{9}$$

where

$I_d + I_{rev}$ is the acoustic intensity at the observer's site, in the absence of the screen, expressed as the sum of the acoustic intensity I_d, in a direct field,

$$I_d = \frac{P}{4\pi\left(s_o + x_o\right)^2} \tag{10}$$

and in a reverberant field

$$I_{rev} = \frac{4P}{R}\quad; \tag{11}$$

while $I_{dif} + I_{rev}$ is the acoustic intensity at the same point, in the presence of the screen, in a diffracted field, expressed by the relation

$$I_{dif} = I_e\left(\frac{x_r}{2x_o}N_I\right)^2 \tag{12}$$

where P is the power of the acoustic source while I_e is the acoustic intensity in front of the screen.

Using the above notations the equation (9) becomes:

$$\Delta L_{cs} = 10\lg \frac{4}{N_I^2} \cdot \frac{1 + \dfrac{16\pi\left(s_o + x_o\right)^2}{R}}{1 + \dfrac{64\pi\left(s_o + x_o\right)^2}{N_I^2} \cdot \dfrac{1}{R}} \tag{13}$$

Because the term $\Delta L_{fs} = 10\lg 4/N_I^2$ represents the attenuation of a screen in a free field, equation (13) can be rewritten as:

$$\Delta L_{cs} = \Delta L_{fs} + \Delta L_c \tag{14}$$

while the term ΔL_c, correcting the attenuation of a screen in a closed space, has the form:

$$\Delta L_c = 10\lg \frac{1 + \dfrac{16\pi\left(s_o + x_o\right)^2}{R}}{1 + \dfrac{64\pi\left(s_o + x_o\right)^2}{N_I^2} \cdot \dfrac{1}{R}} \tag{15}$$

3. Numerical results

The correction term ΔL_c has been calculated for different values of the absorbtion constant, ($R = 50$ m^3 ÷ 1000 m^3) and for different distances ($x_o + s_o$ = 2,6,10,14 m).

Fig. 2 shows the ΔL_c attenuation of a semi-infinite screen in a closed space, for different distances between the source and the observer (SO = 2m÷14m) depending on the Fresnel parameter *v* and on the room constant R .

Table 1

v	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
N_I^2	0,166	0,050	0,024	0,012	0,008	0,005	0,004	0,003	0,0025

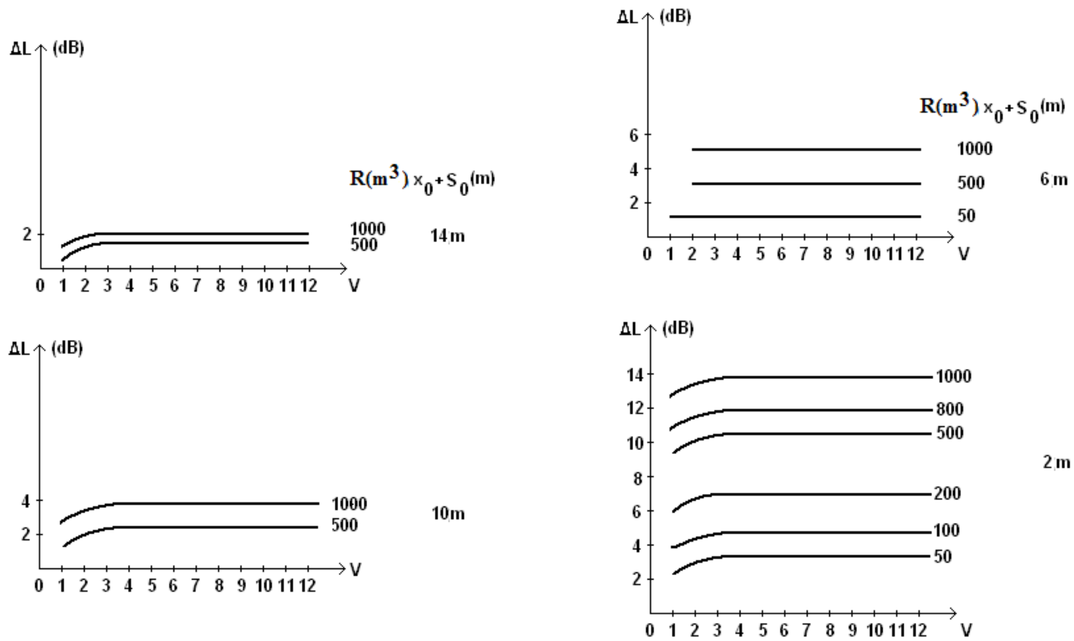

Fig.2

To calculate ΔL_c, for a semi-infinite screen, the values of N_I have been calculated depending on the parameter *v*. These values are listed in Table 1. The level of the corrected attenuation, in case of a closed space, considering the constant *R* equal to 1000 m^3, for different values of the distance between the source and the observation point, is illustrated in fig.4. For low frequency the screen's attenuation is very low, up to 5 dB. This attenuation increases proportionally with the square root of the acoustic signal's frequency.

4. Experimental results

In order to verify the theoretical results presented above, the attenuation of a screen, placed in a classroom (12/6/3,5m) as well as in an anechoic chamber, has been measured.

The anechoic chamber ensures the conditions of a free field. A semi-reverberant field has also been created by placing some supplemental reflective surfaces.

The block diagram of the measurement chain is shown in fig.4. The signal generated by a loudspeaker is received behind the screen by the help of a microphone and analysed on a heterodyne analyser connected to a level recorder.

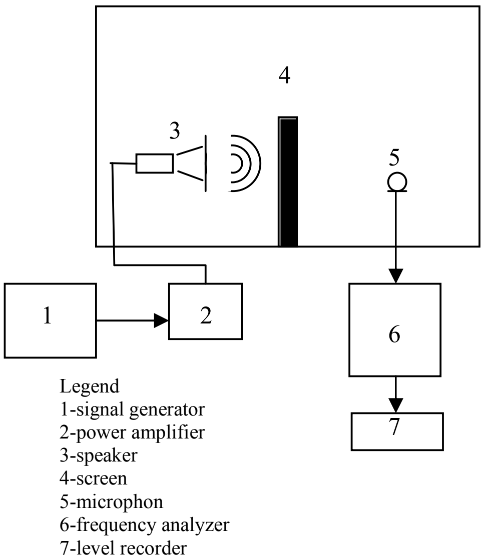

Fig.4.

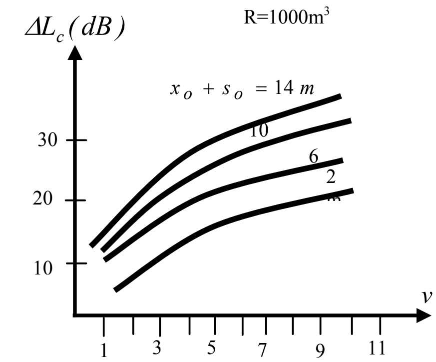

Fig.3.

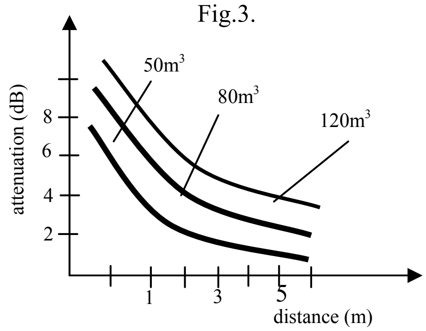

Fig.5

The acoustic signal has been browsed on audio frequencies. The measurements were performed both in the presence and in the absence of the screen, at the same measurement points. The points were located in a close and a remote space behind the screen. Figure 5 shows the measured spectrograms, in the presence and in the absence of a screen (a 1,5x1,5x0,03 m wooden screen) in a point located in the near field behind the screen in a 70 m^3 semi-reverberant room. Fig. 6 shows the values of the attenuation measured in three types of rooms, having the volumes: 50m^3, 80m^3 and 120 m^3, respectively, for distances between 0.5m and 5.5 m.

5. Conclusions

Two special cases have been noticed when introducing a screen. In the first case, the screen was placed in a free field while in the second one in a reverberant field.

If the field is free, the absorption value is equal to the unity while the room constant *R* tends towards infinite. Thus, the equation [13] reduces to

$$\Delta L_c = 10\lg\frac{4}{N_I^2} = -6 + 10\lg N_I^2 \tag{16}$$

For the second case, $1/R << (s_o + x_o)^2$, there results

$$\Delta L_c = 10\lg 1 = 0\,dB \tag{17}$$

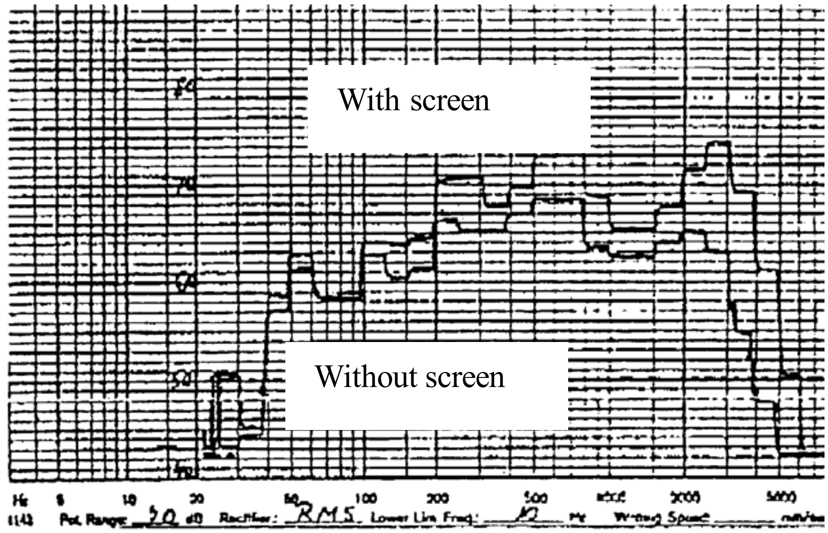

Fig. 6.

The following conclusions can be drawn on the basis of the theoretical and experimental results:

a) In closed spaces, the presence of an absorbing screen plays the role of a functional structure; at the same time, it is difficult to separate the attenuation produced by the diffraction of the edge of the screen from the modifications of the attenuation produced by the presence of the screen.
b) For the same distance between the source and the observer and the same Frensnel parameter *v* the correction ΔL_c is quite small if the room constant *R* is very large (fig.2).
c) For the same room constant *R* and the same parameter *v* the correction ΔL_c increases by increasing the distance.
d) In semi-reverberant closed spaces, the attenuation produced by a semi-infinite screen is small for large distances between the source and the observer, irrespective of the room constant *R*; for small distances ΔL_c, attenuation increases with the room constant.

R E F E R E N C E S

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