5. Building acoustics

5.1. General description

Noise is a factor having negative impact upon a person, decreasing the capacity for work and damaging health. Therefore it is one of the tasks of the building acoustics to protect people from daily noises in different buildings when these are designed. In the developed countries of Europe there are national standards that ensure protection of people against particular noises. Such a building standard has been developed also in Latvia [2]. It is planned to develop more or less uniform standards of building acoustics in Europe in further perspective.

Noises in buildings can be divided into groups based upon the type of their formation and dissemination.

1. If noise in the building has got formed in a room and expands in the air via walls to the nearby rooms the insulation of such dissemination of sound is characterised by the insulation of sound in the air index R'_w , and it is measured in dB. It is the figure with which the sound insulation of internal limiting structures of building, as well as via nearby structures – bypasses, is assessed. Under the laboratory conditions when the bypasses are eliminated, the sound insulation of an internal limiting structure of a building is characterised by the insulation index of sound in the air R_w (dB).
2. If noise gets formed in the result of a stress when some objects come into contact with the limiting structures of the building it is called stress noise and its insulation is characterised by the reduced stress noise level index $L'_{n,w}$ (dB). This value characterises insulation of stress noise under actual conditions including the dissemination of sound via bypasses. Under the laboratory conditions when the bypasses are eliminated the reduced stress noise (stress sound) level index $L_{n,w}$ (dB) is obtained.
3. If noise gets into a building from outside via external limiting structures of the building it is characterised by the insulation index of sound in the air $R'_{tr,s,w}$ (dB), which assesses the sound insulation between a room and external territory.

The above characteristics of limiting structures depend greatly upon frequency and this dependence can be measured both by tests in the particular buildings, or under the laboratory conditions (in cases No. 1 and 2)

5.2. Sound measurements

An ear of a young person detects a sound within the frequency interval of 16–20 000 Hz (along with the age this interval gets narrower) and within the limit of sound pressure of $2 \cdot 10^{-5}$ to 20 Pa. A human ear is most sensitive within the frequency interval 1000–5000 Hz. The sound with the frequency below 16 Hz is called infrasound, and the sound with the frequency above 20 000 Hz is called ultrasound. The lowest sound intensity which a human ear still can detect is called the threshold, and the highest is called the pain margin. For the purpose of characterising so wide range of sound pressure or intensity it is useful to introduce a measurement unit external to the system dB with the following formulae:

$$L = 20 \cdot \lg \frac{p}{p_0} = 10 \cdot \lg \frac{I}{I_0} \qquad (5.1)$$

where p – sound pressure, Pa;

p_0 – hearing threshold, $2 \cdot 10^{-5}$ Pa, at approximately 1000 Hz;

I – sound intensity, W/m² ($I = \frac{p^2}{\rho v}$);

I_0 – zero level sound intensity, 10^{-12} W/m^2 ($I_0 = \frac{p_0^2}{\rho v}$);

ρ – air density, approximately 1.2 kg/m^3;

v – sound dissemination speed in the air, 343 m/s.

For the purpose of determining the value L the hearing function of a human air is taken into consideration (dependence of a human hearing upon frequency).

When the sound waves are falling to the limiting structures the sound is partially reflected and it is partially absorbed. The intensity of the absorbed sound is determined by the sound absorption rate α:

$$\alpha = \frac{I_{abs}}{I_{krit}} \tag{5.2}$$

where I_{abs} – intensity of the absorbed sound;

I_{krit} – intensity of the sound falling to the construction.

The value α may vary within the limits from 0 to 1 and it is greatly dependent upon the sound frequency. When the areas of the surface of individual elements of a room are multiplied with the rates of sound absorption of the corresponding materials the equivalent absorption area of the room A is obtained:

$$A = \sum_i \alpha_i \cdot S_i \tag{5.3}$$

where S_i – area of the surface of the n – th element, m^2;

The equivalent absorption area is equal to such imagined area of the surface which absorbs 100% of the sound.

If a sound is formed in a room the sound will fade gradually when the source of the sound is switched off. The time period during which the sound level decreases by 60 dB is called the reverberation time (T). In between the reverberation time T, absorption area A (m^2) and volume of the room V (m^3) there is Sabine relation:

$$T = 0{,}16\frac{V}{A} \tag{5.4}$$

When the sound disseminates via the limiting structure from one room into another the sound insulation is characterised by the sound insulation index R_W vai R_W':

$$R_w = 10 \cdot \lg\frac{I_1}{I_2} \tag{5.5a}$$

$$R'_w = 10 \cdot \lg\frac{I_1}{I_2'} \tag{5.5b}$$

where I_1 – intensity of the sound falling to the limiting structure;

I_2 – intensity of the sound that has passed through the limiting structure, bypasses not included (under the laboratory conditions);

I_2' – taking into consideration the bypasses of the sound via other structures.

As it is more difficult to measure the sound intensity than the sound pressure measurements of the sound level L are used for measuring the sound insulation indices. A sound source is placed in one (primary) room and the receiver is placed in the second (secondary) room. When the reverberation time of the secondary room is measured it is possible to determine the equivalent absorption area of the room (A_2) according to the Sabine formulae and then the sound insulation indices are calculated based upon the following formulae:

$$R'_w = L_1 - L_2' + 10 \cdot \lg \frac{S}{A_2} \qquad (5.6a)$$

$$R_w = L_1 - L_2 + 10 \cdot \lg \frac{S}{A_2} \qquad (5.6b)$$

where L_1, L_2 – average sound level of rooms (L_2' – taking into consideration bypasses);

S – area of the surface of the limiting structure, m^2.

As the values R'_w and R_w depend upon frequency the standard frequency curve is used for determining the average index.

The index of the level of the reduced stress noise or stress sound is measured in a similar way to the sound insulation index. The difference is that the stress sound is created by a special generator of stress sound. There are five weights in this generator (weight of each of them amounts to 500 g) falling onto the floor from the height of 4 cm one after another 10 times per second, thus creating a stress sound in the primary room. The index $L'_{n,w}$ is determined based upon the following formulae:

$$L'_{n,w} = L_2 + 10 \cdot \lg \frac{A_2}{A_0} \quad ; A_0 = 10\ m^2. \qquad (5.7)$$

In the analogous way to the determination of the mean level of the values R'_w and R_w the standard frequency curve is used for determining also $L'_{n,w}$.

5.3. Sound absorption and insulation

Sound absorption of different materials is applied in practice for the formation of sound insulation layers. The Latvian Building Standard LBN 016-03 «Building acoustics» [2] regulates the following values of the sound insulation: sound insulation index R'_w, reduced stress noise level index $L'_{n,w}$ and minimum insulation index of the sound in the air $R'_{tr,s,w}$ depending upon the level of the external noises. Insulation indices of the sound in the air shall be at least compliant to the values specified in the Tables of the Appendices No. 2 and 3 of the LBN 016-03, and the reduced indices of the stress noise level shall not exceed the values specified in the Tables. The values of the index R'w specified in the Tables of the Appendix is the required sound insulation between the rooms in the vertical and horizontal direction. The index $L'_{n,w}$ marks the required insulation of stress noise in all the directions (vertical, horizontal and diagonal). Compliance to the requirements of the insulation of stress noise is defined for the rooms with the area of the floor surface of at least 2.5 m^2.

For example, the Building Standard LBN 016-03 [2] defines the requirement that in between the living rooms of apartments the insulation index of the sound in the air R'w shall not be below 54 dB.

Four types of limiting structures by which it is possible to achieve the necessary sound insulation are described in the sources [1]. Thick and massive walls is the sound damping element in three of the above referred types. Sound permeability of a massive wall is determined by the so called mass law in compliance with which the sound insulation index increases within the limits of particular frequency along with the increase of the frequency and as per the area of a restricted mass of the wall m' (kg/m^2):

$$R = 20 \cdot \lg(f \cdot m') - 47; \quad (dB) \qquad 5.8)$$

where f – sound frequency, Hz.

For example, as it has been described in the sources [1], at the frequency of 244 Hz and m'=410 kg/m^2 the sound insulation index R which is calculated based upon the formula (5.8) produces 53 dB. For the wall structure of the system «Dobeles panelis» where only the sound insulation of the reinforced concrete layer is taken into consideration (thickness of the reinforced concrete wall is 0.15 m; density 2400 kg/m^3 [3]; m'=360 kg/m^2) when applying the formula (5.8) 52 dB are obtained.
Sound insulation is additionally increased also by the layers of the light material (expanded polystyrene foam) heat insulation layers which are located on both sides of the massive reinforced concrete structure in the wall structures of the system «Dobeles panelis». Thus it can be expected that the wall structures of the system «Dobeles panelis» will be characterised by a good sound insulation index. See the systems analogous to the system «Dobeles panelis» and their technical data (including the sound insulation) in the Internet [4, 5, 6].
The above theory is confirmed by the acoustics tests of the system which is analogous to the system «Dobeles panelis» «PLASTBAU-3» performed in Italy in compliance to the standard UNI EN ISO 717 Part 1, 1997 (protocol No. 141742). The tested building structure with the area of 11.8 m^2 contains 150 mm thick reinforced concrete wall element with 50 mm thick EPS layer with the density of 30 kg/m^3 on both sides. Taking into consideration the external finish layers of the structure the total thickness of the structure amounts to 320 mm. Following the acoustics tests it has been established that the insulation index of the sound in the air of this building structure R'_W = 60 dB.

5.4. Sources

1. I. Veits. Protection against sound transmission in buildings and relevant international standards.– Scientific seminar: «Heat engineering of the limiting structures of buildings». – Riga, 16.–17.03.2000. pages 18-1 to 18-13.
2. Latvian Building Standard LBN 016-03 «Building acoustics».
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