Amendment of Calculation Method Airborne Soundproofing of Light Multi-Layer Enclose Structures of Residential Buildings

Jasur Gayratugli Rashidov

Senior Lecturer of Department "Building and Structures" at Tashkent Institute of Architecture and Civil Engineering, Tashkent, Uzbekistan

Email: jasrash55@gmail.com

Abstract

This research paper describes airborne soundproofing of multilayer light enclose structures at the stage of designing and reconstruction of residential buildings, with the help of which it is possible to obtain a sufficiently reliable calculation, representing the correct passage and radiation of the sound stream in these structures, taking into account the finiteness of the dimensions, fixing conditions, physical and mechanical characteristics of materials and the method of proper installation.

Keywords: Airborne Soundproofing, Frequencies, Multilayer Structures, Residential Buildings.

1. Introduction

At present, in the Republic of Uzbekistan, special attention is paid to ensuring the well-being of the people, which is the corresponding goal of implementing the tasks identified in the Strategy of Actions for the further development of the country for 2017–2021 [1]. One of them is the construction of modern buildings. Decree of the President of the Republic of Uzbekistan dated March 13, 2020 No. DP-5963 "On additional measures to deepen reforms in the construction industry of the Republic of Uzbekistan", the National Database of Legislation, as well as other regulatory legal acts adopted in this area, contribute to the achievement of these goals. Today, an urgent task is to ensure the acoustic comfort of the premises, associated with the rational choice of the enclose structures at the design stage.

Construction and installation work must be designed and executed in such a way that the sound perceived and in the vicinity of people is minimized or completely isolated.

Therefore sound level that will not affect their health and will allow them to work in satisfactory conditions. Based on numerous scientific studies, as a result of uncontrolled sound, it can negatively affect human health by the occurrence of various diseases such as: cognitive impairment of the fetus in reproductive people, sleep disturbances, tinnitus, irritation and dysfunction of some human organs (liver, kidneys, etc.). As a result, sound exposure should be considered not only as a source of inconvenience, but also as a source of harm to human health. Sound waves collide with other surfaces, causing them to vibrate and transmit the negative effects of the air around them in adjoining rooms, in which, in terms of sound quality, in many cases this is not enough, since comfort also depends on the sound level of the emitter. Many of these problems are easily resolved at the design stage, while other cases require more costly corrective measures. In particular, one of the main tasks at the design stage is the use of lightweight multi-layer enclosing structures with a relatively small mass that allows to reduce the load and reduce the material consumption of building construction. In this case, it is necessary to ensure the fulfillment of the requirements for the isolation of airborne sound and their expedient distribution of the sound oscillatory processes of the enclosing structures. The rational use of the partitions of sound oscillatory processes

ensures that the requirements for the strength and stability of structures are met, which makes it possible to increase the speed of installation and reduce its labor intensity.

Sound insulation in the resonant frequency zone of a multilayer structure in strategic buildings may be less than one wall with a total mass of both structures.

2. Methods of Research

Researches have shown that with increasing thickness of the air gap and the mass of both plates, the resonant frequency of the mass-elastic-mass system shifts to the low-frequency region. An increase in the sound insulation of multilayer structures is observed at medium and high frequencies lying above the resonance frequency of the mass – elastic – mass system, approximately in an octave.

As the frequency increases from the resonance frequency of the mass – elastic – mass system for multilayer structures with an air gap to the medium and high frequencies, sound insulation takes the form of successively sufficiently high maxima in the zone of ant resonant frequencies of the air gap equal to the sum of sound insulation the first and second structures and narrow minima at the resonant frequencies of the air gap equal to the sound insulation of a single-layer structure with a total mass of both plates. Therefore, in the field of medium and high frequencies, a real multilayer structure has a clear advantage over a single-wall structure of equal mass, i.e. its sound insulation increases due to broad maxima in the region of ant resonant frequencies of the air layer in the controlled zone.

The partition is made of two sheets of a 16 mm thick slab with a bulk density of $\gamma = 680 \text{ kg} / \text{m}^3$ along the frame, with an air gap of 50 mm thick filled with mineral wool slabs, $\gamma = 35 \text{ kg} / \text{m}^3$ and two gypsum plasterboards of 12.5 mm thick each with a bulk weight of $\gamma = 800 \text{ kg} / \text{m}^3$ on a relative of 87 mm filled with a minelayery $\gamma = 48 \text{ kg} / \text{m}^3$ with a thickness of 50 mm (Figure 1)

Figure 1. Multi-layer enclose structures acting as partitions of a residential building

The design was used in the construction of inter-apartment partitions at the stage of construction of a residential building in the house on the street. Bakunin, 147, in the city of Penza (Figure 2).

Figure 2. The process of to check soundproofing airborne noise during the construction of a residential building

We build the frequency response of sound insulation for one sheet of drywall in accordance with KMK 2.01.08-20 Noise protection. The coordinates of points B and C are determined by the table.

$$f_B = \frac{13500}{16} = 843 \approx 800 \text{ Hz}; \quad R_B = 30,5 \text{ dB}$$

$$f_C = \frac{27000}{16} = 1687,5 \approx 1600 \text{ Hz}; \quad R_C = 26 \text{ dB}$$

From point B, draw a segment BA to the left with a slope of 4.5 dB per octave, and from point C to the right, draw a segment CD with a slope of 7.5 dB per octave.

The broken line ABCD is the frequency response of airborne noise insulation of one drywall sheet.

We build the auxiliary line A'B'C'D' by adding the correction $\Delta R1$ to increase the surface density to the values of the ABCD line.

In this case, the total surface of the fence includes two sheets of chipboard 16 mm each, two sheets of gypsum board with a thickness of 12.5 mm each and mineral wool fillings of 50 mm - $\gamma = 48 \text{ kg} / \text{m}^3$, 50 mm - $\gamma = 35 \text{ kg} / \text{m}^3$

$$m_1 = m_2 = \gamma h = 680 \cdot 0,016 = 10,88 \text{ kg/m}^2$$

$$m_3 = (800 \cdot 0,0125) \cdot 2 = 20,0 \text{ kg/m}^2$$

$$m_4 = (48 \cdot 0,05) + (35 \cdot 0,05) = 4,15 \text{ kg/m}^2,$$

when,

$$m_{total} = (2 \cdot 10,88) + 20,0 + 4,15 = 45,91 \text{ kg/m}^2$$

At

$$m_{total}/m_1 = 45,91/10,88 = 4,22 \quad \Delta R_1 = 9,5 \text{ dB}$$

Determine the frequency for the plasterboard sheet f_c :

$$f_c = 38000/12,5 = 3040 \approx 3150 \text{ Hz}$$

We build the auxiliary line A'B'C'D' to the frequency f_B , adding a correction of 9.5 dB to the values of the ABCD line (segment A'B'), then draw a horizontal segment B'C' (point C' corresponds to the frequency f_c), then we draw a segment C'D' with a slope of 7.5 dB per octave (point D' lies outside the normalized range).

We determine the frequency of the main resonance of the structure by the formula

$$f_p = 60 \sqrt{\frac{m_1 + m_2 + m_3}{d(m_1 + m_2) \cdot m_3}}, \text{ Hz}$$

where d – distance between outer covering, $d = 153 \text{ mm}$

$$f_p = 60 \sqrt{\frac{10,88 + 10,88 + 20,0}{0,153(10,88 + 10,88)20,0}} = 47,4 \approx 50 \text{ Hz}$$

At a frequency of 50 Hz, we find the point F with the ordinate at $(4 + 2) \text{ dB}$ below the auxiliary line A'B'

$$R_f = 22 - 4 - 2 = 16,0 \text{ dB}$$

At a frequency of $8 f_p = 400 \text{ Hz}$, we find point K with ordinate

$$R_k = R_f + H + 2 = 17,5 + 27 + 2 = 46,5 \text{ dB}$$

$H = 27 \text{ dB}$.

From point K, we draw a segment KL to a frequency $f_B = 800 \text{ Hz}$ with a slope of 4.5 dB per octave, $R_L = 49,5 \text{ dB}$.

From point L to the frequency $f_c = 3150 \text{ Hz}$, we draw a horizontal segment LM, then a segment MN with a slope of 7.5 dB per octave.

The broken line FKLMN is a frequency response of airborne noise isolation by a partition with an empty air gap.

At a frequency of $1.6 f_p = 80 \text{ Hz}$, mark the point Q with ordinate

$$R_Q = 22,0 + 5 = 27,0 \text{ dB}$$

correction $\Delta R_4 = 5$ and connect it with point F.

Next, we construct the frequency response parallel to the FKLMN line by adding the correction $\Delta R_4 = 5$ dB to its values.

The FQK'L'M'N' broken line represents the frequency response of airborne noise insulation with a given enclosing structure.

In the standardized frequency range of airborne noise insulation is:

Table 1. Frequency range of airborne noise insulation

<i>f, Hz</i>	100	125	160	200	250	315	400	500
R, dB	30,0	33,5	37,0	40,0	43,5	47,0	50,0	51,5

Continuation of Table 1.

<i>f, Hz</i>	630	800	1000	1250	1600	2000	2500	3150
R, dB	53,0	54,5	54,5	54,5	54,5	54,5	54,5	54,5

To determine the index of airborne noise insulation by the considered design of the interroom partition, we compare the frequency response of sound insulation, (Table 1) with the evaluation curve.

The calculation is carried out in the form of table 2.

We determine adverse deviations. The sum is 22 dB, which is less than the required 32 dB.

For the value of the insulation index R_w , we take the ordinate of the downwardly estimated curve in the third-octave band with a geometric mean frequency of 500 Hz, i.e. $R_w = 52$ dB.

Table 2. Evaluation curve

№	Parameters	The geometric mean frequency of the 1/3-octave band, Hz							
		100	125	160	200	250	315	400	500
1	Estimated frequency response R, dB	30,0	33,5	37,0	40,0	43,5	47,0	50,0	51,5
2	EstimatedCurve, dB	33	36	39	42	45	48	51	52
3	Adversedevelopment, dB	3,0	2,5	2,0	2,0	1,5	1,0	1,0	0,5
4	Airborne sound insulation index, R_w , dB								52

Continuation of Table 2.

№	Parameters	The geometric mean frequency of the 1/3-octave band, Hz							

		630	800	1000	1250	1600	2000	2500	3150
1	Estimated frequency response R, dB	53,0	54,5	54,5	54,5	54,5	54,5	54,5	54,5
2	Estimated Curve, dB	53	54	55	56	56	56	56	56
3	Adverse deviation, dB	-	-	0,5	1,5	1,5	1,5	1,5	1,5
4	Airborne sound insulation index, R_w , dB								

3. Conclusion

Consequently, the sound insulation of lightweight building envelopes mainly depends on the physic mechanical characteristics of the materials used, the design of the enclosures, the conditions of connection with adjacent enclosing elements, etc. In this regard, the Anteroom Partition Structure has an air noise insulation index of $R_w = 52$ dB. The anteroom partition meets the regulatory requirements for airborne sound insulation $R_w = R_w^H = 52$ dB

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