

DEVELOPMENT AND APPLICATION OF ACOUSTIC BUILDING STRUCTURES IN HALLS

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The article presents the essential requirements for ensuring acoustic comfort in halls. The study analyzes the effectiveness of using multiresonant acoustic building structures to eliminate multiple reflections in halls. The results of investigations of multiresonant acoustic building structures integrated into the building are presented under real conditions, conducted in the conference hall of the Molodyozhnaya Hotel located on Dmitrovskoye Highway in Moscow and in the production workshop of the Almast Factory in Yerevan.

Keywords: *Helmholtz resonator, multiresonant acoustic building structures, reverberation chamber, reverberation time, sound absorption coefficient*

Introduction

Green construction is a modern field that is dynamically developing all over the world [1- 5].

There are problems of green construction.

1. Use of environmentally friendly, non-allergenic building materials.
2. Reduction of emissions of greenhouse gases, garbage, polluted water.
3. Improvement of air quality, as well as thermal and acoustic characteristics in the building. Building acoustics is one of the most important areas of green construction. Building acoustics solves two important problems.

The first is the reduction of low-frequency and infrasound noise in production buildings, Second, improving the acoustic environment of quality oral speech and music in halls, auditoriums, and recording studios.

Without sound amplification electrical systems, music and the Human Natural Voice, as well as energy, water, soil, are valuable resources that must be conserved.

Why keep the natural sound? The structure of water absorbs energy from the environment. The positive or negative energies of speech and music affect the human body, down to the cell [1]. Therefore, it is necessary to create favorable acoustic conditions of the environment. At the same time, designing rooms with only natural sound completely eliminates the cost of implementing and using sound reinforcement systems.

1.1 Acoustic perception and early reflections

Experimental and psychoacoustic studies show that for high speech intelligibility the arrival time of early reflections should not exceed 0,2 s relative to the direct sound. When early reflections arrive within $t \leq 0,2$ s, the listener perceives the direct sound and reflections as a single acoustic event, which increases perceived loudness without degrading intelligibility. Reflections arriving later than this interval contribute to audible echo and reduce speech clarity. For large halls, longer delays (up to 0,5...0,6 s) may be perceptible; however, such delays are generally considered unacceptable for speech-oriented spaces without electroacoustic support [2].

Reverberation is the result of multiple sound reflections from room surfaces. Excessive reverberation leads to overlapping of successive speech sounds and loss of intelligibility, especially in large-volume spaces. Therefore, control of early reflections and reverberation time is a primary indicator of acoustic quality in halls.

Thus, the indicator of the quality of the sound environment in the audience is the response. Sound reflects differently from different surfaces. Smooth, smooth surfaces reflect sound the way a mirror reflects

light (the angle of incidence equals the angle of reflection). Rough materials reflect sound in many directions, the reflected sound from such surfaces is perceived as blurred, words are unclear. The main indicator of the quality of the sound environment in the auditorium is the reverberation. Reverberation is the phenomenon of multiple reflections of sound from flat, smooth surfaces in a room.

In small auditoriums, the sound reflected from the walls and ceiling reaches the listener quickly after passing short distances, the listener hears the word and the echo of the same word almost simultaneously, and the perception of the word is understandable.

In large auditoriums, the sound reflected from the walls and ceiling, traveling long distances, reaches the listener late, the listener hears the current word of the speaker and the echo of the previous word of the speaker at the same time, the current word and the echo of the previous word are combined and the words are not understood. Reverb, Reverb Delay: Reverb time should be reduced.

Back in 1895, Professor Clement Sabine of Harvard University found one of the main equations of architectural acoustics: Reverberation time is directly proportional to the volume of the room, inversely proportional to the surfaces of the walls, ceiling and floor [1].

$$T = \frac{0,164 \cdot V}{a \cdot S}. \quad (1)$$

1.2 Hall proportions, surface treatments, and reverberation requirements

The acoustic quality of halls depends not only on the applied sound-absorbing or resonant structures, but also on the geometric proportions of the hall, the acoustic treatment of its surfaces, and the reverberation time requirements defined by the functional purpose of the space. A comprehensive and integrated consideration of these factors is essential for achieving high speech intelligibility and musical quality.

Geometric proportions of halls

The ratios between the height, width, and length of a hall have a significant influence on the distribution of room acoustic modes and the uniformity of the sound field. Unfavorable proportions may lead to standing waves and pronounced resonances, which degrade speech intelligibility and musical perception. In practice, it is recommended to avoid simple integer ratios (e.g., 1:1:2) and to apply proportions that ensure a more uniform modal distribution, such as 1,0:1,4:1,9 or similar ratios.

Surface treatments and material selection

The materials used for floors, walls, and ceilings affect sound reflection and absorption in different ways. Floor constructions should reduce impact noise and avoid excessive specular reflections. Certain wall surfaces, particularly rear and lateral walls, should be treated with materials having higher sound absorption coefficients in order to prevent secondary and multiple reflections. At the same time, a balanced combination of reflective and absorptive surfaces is required to create a lively but controlled acoustic environment.

Types of halls and reverberation time requirements

Acoustic requirements vary considerably depending on the functional type of the hall. In lecture halls and classrooms, speech intelligibility is the primary criterion; therefore, the allowable reverberation time should be relatively short. In theatrical halls, a balanced reverberation is required, whereas concert halls intended for chamber or symphonic music require longer reverberation times, which enhance musical richness and fullness.

Thus, the proposed multi-resonance acoustic building structures are most effective when applied as part of an integrated acoustic design strategy that combines appropriate hall geometry, surface treatment, and reverberation time corresponding to the hall's functional purpose.

1.3 Hall geometry, surface treatment, and hall types

The acoustic quality of halls depends not only on sound-absorbing structures but also on hall geometry, surface materials, and functional purpose.

Hall proportions (geometry)

Geometric proportions significantly influence modal distribution and reverberation control. Unfavorable ratios between height, width, and length may result in strong standing waves and uneven sound fields. For halls designed primarily for natural sound, the following approximate ratios are recommended:

- Small speech halls: $H : W : L \approx 1,0 : 1,4 : 1,9$
- Medium multipurpose halls: $1,0 : 1,5 : 2,2$
- Music halls: $1,0 : 1,6 : 2,4$

Equal or integer-multiple dimensions should be avoided to prevent strong axial resonances.

Surface materials and acoustic treatment

Surface finishes play a critical role in acoustic performance. Floor constructions should reduce impact noise and low-frequency buildup. Side walls should be partially treated with higher sound-absorption materials to prevent secondary echoes, while rear walls often require increased absorption or diffusion to suppress late reflections. Ceilings should combine reflective zones for beneficial early reflections and absorptive zones for reverberation control.

Types of halls and recommended reverberation time

Different hall types require different reverberation times (RT):

- Lecture and conference halls: $0,6 \dots 0,9 \text{ s}$
- Drama theaters: $0,8 \dots 1,2 \text{ s}$
- Chamber music halls: $1,2 \dots 1,6 \text{ s}$
- Symphonic concert halls: $1,8 \dots 2,2 \text{ s}$

Multi-resonance absorbers are especially effective in adjusting reverberation time in the low-frequency range, where conventional absorbers are inefficient.

In halls and auditoriums, the biggest influence on the reverberation time is the sum coefficient α of sound absorption of the walls, ceiling, floor, and sound-absorbing structures.

Damping of sound energy is carried out due to the multiple incidence and reflection of sound waves inside the resonator and reaches its peak when the frequency of the sound wave falling on the resonator coincides with the frequency of the resonator's own oscillations.

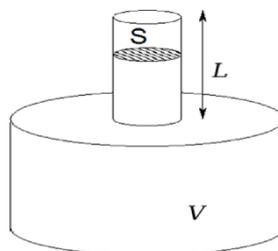


Fig. 1. Helmholtz resonator oscillator system

The Helmholtz resonator is an oscillatory system. The air in the hole is the oscillating mass, and the air in the vessel acts as an elastic element, a spring (fig. 1).

The resonance frequency of the resonator in the form of a cube with a side of 33 cm (with a volume of $0,33 \times 0,33 \times 0,33 = 0,036 \text{ m}^3$):

$$f = \frac{c}{\lambda}, \lambda = \sqrt[3]{V} = 0,33 \text{ m}, f = \frac{340}{0,33} = 1030 \text{ Hz} . \quad (2)$$

While effective in the low-frequency range, the resonator has a significant disadvantage in that it provides noise reduction only in a very narrow band of frequencies, having a single resonance frequency of 1030 Hz.

Materials and Method

In order to increase the efficiency of the Helmholtz resonator in the low-frequency and infrasound range, in order to obtain several values of the resonance frequency, the author of the article developed multi-resonance acoustic systems at the Research Institute of Construction Physics of the Russian Academy of Architecture and Construction Sciences in Moscow (fig. 2) [6].

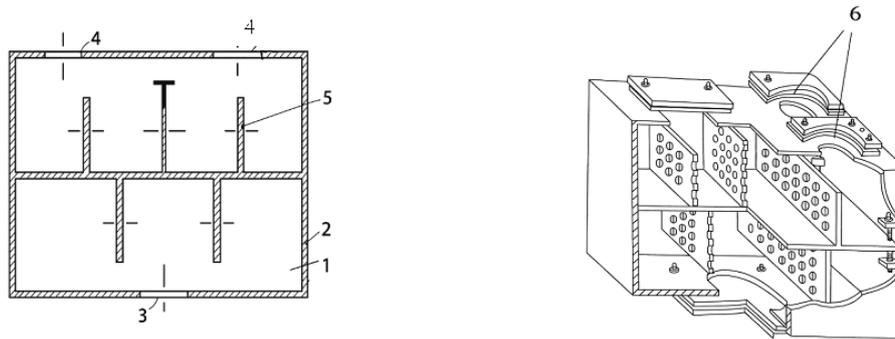


Fig. 2. Multi-resonance low-frequency sound absorber, in the interior of which, parallel to the input holes, a fine-grained partition is placed on elastic links, damping suspensions

The resonator with rigid nipple walls (1) is a hollow parallelepiped or cube (2), in the cavity of which fine diffraction gratings are placed parallel to the input holes (3 and 4) on adjustable elastic links on damping suspensions.

Diffraction screens (6) are installed on the inlet holes (3, 4 and 5), which are adjusted with screws. The resonator is a "mass-spring" type oscillator system. "Mass" (3, 4 and 5) is the mass of air in the inlet ports. The elasticity of compressed air in the cavity acts as a "spring". In addition, the masses of air in the holes of the diffraction grating are also capable of resonant oscillations, as well as the masses of the grating itself. All together form a multiresonance system.

The resonant frequencies depend on the volume of the cavity. By moving the diffraction grating with the help of adjustable springs, we increase the volume of the cavity, the elasticity of the oscillatory system, lowers the resonance frequency (2).

When the sound waves fall on the input holes (3 and 4), the diffraction of sound waves occurs on the screens (5) - bending, bending of the sound waves, as a result of which the oscillating mass increases in the input holes (3 and 4), which lowers resonance frequency. Further reduction of the resonance frequency to 63...80 Hz is done by reducing the stiffness of the springs. The multi-resonance efficiency of sound absorption of the resonator is in the range of 63...500 Hz.

The other resonator is a hollow-walled hollow cube (1) with an inlet hole (3), separated from the inside by an inclined gravel partition (4). The resonator has a diffraction screen (6) with adjustment screws (7), which is placed in front of the hole (3) (fig. 3) [7].

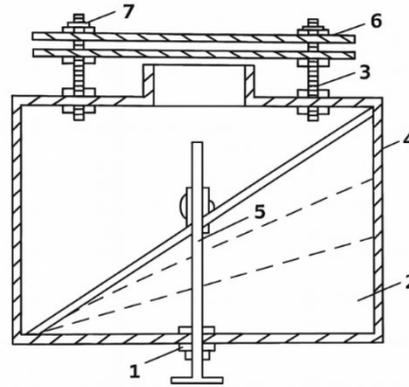


Fig. 3. Multi-resonance low-frequency sound absorber, with a diagonal, adjustable screws, the finegrained septum is installed

By changing the volume of the cavity through the inclined partition (4), we change the resonance frequency. For example, by increasing the volume, the elasticity of the oscillatory system, we lower the resonant frequency.

When a sound wave falls on a diffraction screen, the plates of the screen vibrate. A "mass-spring" oscillatory system occurs.

The resonant frequency is shifted to a lower frequency range by increasing the mass of the plates of the diffraction screen and decreasing the stiffness of the springs:

$$f = \frac{1}{2\pi} \cdot \sqrt{\frac{k}{m}}, \quad (3)$$

k is the stiffness of the spring, m is the mass of the plates.

The thickness of the plates of the diffraction screen is less than 1 mm, and it is placed at a distance δ from the entrance hole (3), which is determined by:

$$\delta \leq 7,3 \cdot 10^{-3} \cdot \lambda, \quad (4)$$

where λ – sound wavelength, cm.

To determine the effectiveness of resonators, first measure the Reverberation Time of an empty audience without resonators, then the Reverberation Time of an audience with resonators.

If the response time is reduced, the resonators are efficient.

The efficiency of the resonators was also measured in the reverberation chamber of the Research Institute of Construction Physics of the Russian Academy of Architecture and Construction Sciences. To determine the effectiveness of resonators, the reverberation time is first measured without resonators in an empty reverberation chamber, then in a reverberation chamber with resonators. If the response time is reduced, the resonators are efficient.

Tests have shown that the resonators reduce the sound pressure level in the low-frequency range from 20 to 700 Hz by 3 to 7 dB, and in the medium frequency range from 700 to 2000 Hz by 9 to 12 dB.

Results and Discussions

The efficiency of the resonator was determined in 3 stages:

1. investigation of a separate resonator in the plane sound wave field of the interferometer, determination of the sound absorption coefficient,
2. investigation of the resonator assembly in the diffuse sound field of the reverberation chamber,

3. investigation of the resonator assembly in real conditions, in an exact hall, in the Conference Hall of the Molodyozhnaya Hotel on Dimitrovskaya Highway in Moscow and in the production workshop of the Almast Plant in Yerevan.

Experimental studies were carried out at the Research Institute of Construction Physics of the National Academy of Architecture and Construction Sciences of the Russian Federation, Moscow.

Stage 1 of the research

Investigation of a separate resonator in the plane sound wave field of an interferometer: determination of the sound absorption coefficient

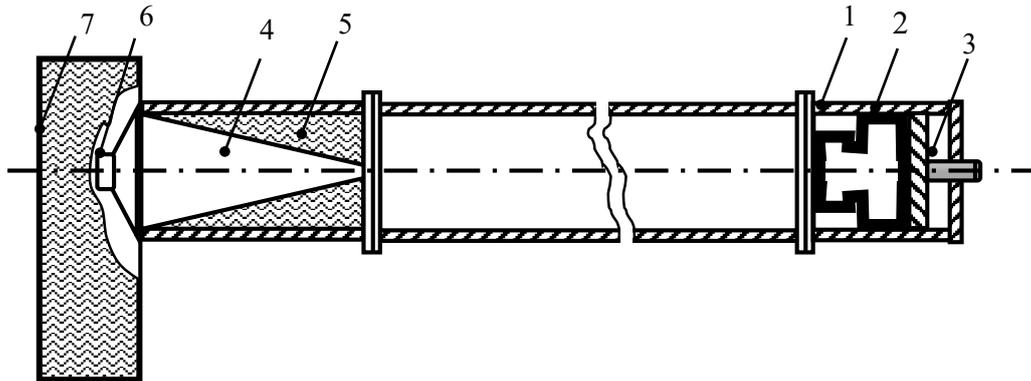


Fig. 4. Developed, tested and patented interferometer. Scheme of the study of a separate resonator in the field of a plane sound wave of an interferometer: 1-acoustic tube, 2- resonator under test, 3- cylinder rod, 4- conical sound tube , 5- sound-absorbing material, 6- electrodynamic radiator, 7- sound-absorbing housing

The proposed interferometer (fig. 4) is a tube (1) with a square cross-section, on one side of which is located the resonator under test (2), mounted on a cylinder (3) [8, 9].

On the other side of the tube are located a conical sound tube (4) wrapped with sound-absorbing material (5), an electrodynamic radiator (6), which is tightly attached to the conical sound tube (4) and is located in a sound-absorbing housing (7).

In the case of interference, the difference in the phases of the oscillations remains constant and determines the magnitude of the amplitude of the wave obtained from the superposition.

The wave must be flat, perpendicular to the front, otherwise the measurements of the maximum and minimum of the interference will create an inaccurate image.

A plane sound wave is a wave whose constant phase front surface is a plane.

To obtain a plane sound wave, the length of the sound wave must be greater than the diameter of the interferometer: $\lambda > 1,71 \cdot D$.

In this case, the curvature of the plane sound wave near the sound source and near the resonator under test is smoothed out at some distance along the length of the interferometer tube.

The reliability of the measurements requires that 2 maxima and 2 minima of the wave be located along the length of the tube, that is, the length of the tube should be $L > 1,5 \lambda = 7,5$.

$$f = \frac{c}{\lambda}, \quad \lambda = \frac{c}{f} = \frac{344}{70} \approx 5,0 \text{ m}.$$

It has been experimentally proven that the appropriate accuracy of measurements can also be obtained with 1 maximum and 1 minimum of the wave: $L > 0,75 \cdot \lambda$.

A new method for determining the sound absorption coefficient of a resonator in a plane (perpendicular to the front) sound wave field of an interferometer has been developed, tested and patented, which is

distinguished by higher efficiency due to the reduction of the places of measurement of sound pressure values and is carried out at one arbitrary point of the interferometer [8, 9].

Compared with the prototype interferometer, which allows testing only cylindrical resonators, the proposed interferometer allows studying cubic, parallelepipedal resonators. It has been experimentally proven that the appropriate measurement accuracy can also be obtained by reducing the length of the interferometer from 7 to 2 meters. By measuring 1 maximum and 1 minimum instead of 2 maximums and 2 minimums of a standing wave placed along the length of the tube.

Along the length of the outer surface of the interferometer (1), at an arbitrary point, a microphone is placed (shown) to receive elastic vibrations. An acoustic field is created in the tube (1) through the sound tube (4) by means of the electrodynamic radiator (6).

Sound pressure is measured at a certain frequency of the sound field. During the sound pressure measurement, the frequency is constantly changed until a frequency value is obtained at which the sound pressure at that same point takes on a minimum value.

From the measured minimum and maximum values of sound pressures, the reflection coefficients ε and the sound absorption coefficient α are determined by calculation formulas.

The determination of the sound absorption coefficient is reduced to determining the difference between the sound pressure levels at the maximum and minimum:

$$\Delta L = 20l g \frac{P_{max}}{P_{min}}, \tag{5}$$

where P_{max} is the maximum sound pressure, P_{min} is the minimum,

$$P_{max} = A + B, \quad P_{min} = A - B, \quad A \text{ is the amplitude of the incident wave, } B \text{ is the reflected one.}$$

$$\text{Where: } A = \frac{P_{max} + P_{min}}{2}, \quad B = \frac{P_{max} - P_{min}}{2}.$$

ε the modulus of the reflection coefficient will be:

$$|\varepsilon| = \frac{\frac{P_{max}}{P_{min}} - 1}{\frac{P_{max}}{P_{min}} + 1}.$$

$$\text{Since: } \frac{P_{max}}{P_{min}} = 10^{\frac{\Delta L}{20}}.$$

$$|\varepsilon| = \frac{10^{\frac{\Delta L}{20}} - 1}{10^{\frac{\Delta L}{20}} + 1}.$$

The value of the sound absorption coefficient will be determined by:

$$\alpha = 1 - |\varepsilon|^2 = \frac{4}{10^{\frac{\Delta L}{20}} + 10^{-\frac{\Delta L}{20}} + 2}. \tag{6}$$

Using the values of the last two formulas, a graph is constructed (fig. 5), which allows determining the ε reflection and α sound absorption coefficients by the difference in sound pressure levels ΔL .

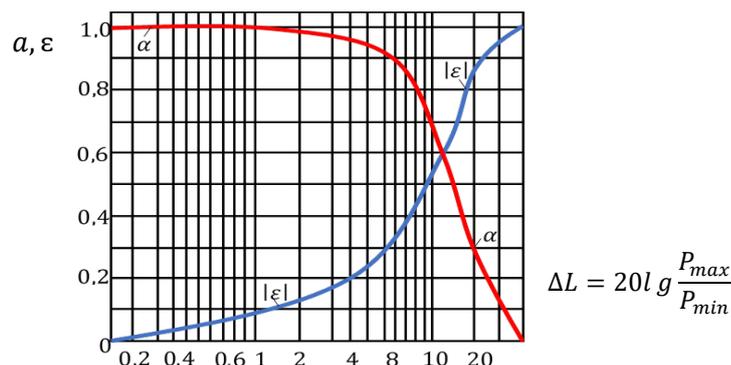


Fig. 5. Dependence of ε reflection and α sound absorption coefficients on sound pressure levels

Stage 2 of the study

Investigation of the resonator structure in the diffuse sound field of the reverberation chamber

In accordance with the norms of the International Organization for Standardization Committee on Acoustics, the reverberation method requires a large room with a volume of 180 to 200 m^3 , with non-parallel walls with a slope of 10^0 [10].

In order to reduce the cost and time of research, the structure consisting of 24 sound resonators is examined in the reverberation chamber only after receiving positive test results in the plane sound wave field of the interferometer.

In the reverberation chamber, the sound is completely reflected from the walls, ceiling, and floor. The walls, ceiling, and floor are finished with sound-reflecting materials, such as high-quality cement or marble.

In the reverberation chamber, the diffuse sound field is created by the irregular shape of the reverberation chamber: the walls are not parallel and are uneven. In the reverberation chamber, the sound is completely reflected from the surrounding surfaces, and at each point the sound pressure is on average the same, and the arrival of sound waves from different directions is equally likely.

Isolated from external sounds and vibrations, the Sound Field in the Anechoic Chamber is created by reference sources of noise, with 4 loudspeakers, electrodynamics, directed to the corners of the Anechoic Chamber.

Sound pressure level 80 ± 3 dB, operating frequency range 60 to 8000 Hz.

Measurements in the Anechoic Chamber were made using microphones - receiver microphones, and devices measuring the noise pressure level - sound level meters by Brule and Kier [11].

The main indicator of the quality of the acoustic environment in the reverberation chamber is the reverberation.

The reverberation method makes it possible to determine the total sound absorption coefficient of various objects, furniture, and resonators, which is impossible to achieve in interferometry.

The higher efficiency of the checkerboard arrangement of resonators in the reverberation chamber has been experimentally proven, compared to the serial and mixed arrangement of resonators. The checkerboard arrangement of resonators increases the total sound absorption of the resonator structure due to diffraction, which occurs as a result of the curvature of sound waves in the spaces between the resonators.

To determine the efficiency of the resonators, we first measure the standard reverberation time of the empty reverberation chamber without resonators - the time during which the sound pressure level decreases by 60 dB after turning off the sound source. Then we measure the standard reverberation time of the reverberation chamber with resonators.

If the reverberation time has decreased, then the resonators are efficient.

Knowing the standard reverberation times of the empty reverberation chamber and the reverberation chamber with resonators, we can determine the total sound absorption in the chamber without resonators and with resonators.

In the reverberation chamber, the greatest influence on the reverberation time is the sum of the sound absorption coefficients a of the walls, ceiling, floor, and sound-absorbing structures.

Stage 3 of the study

Research on the resonator complex in real conditions in halls and workshops

We tested the resonators in the hall and workshops. In a hall with low sound quality, the sound reflected from the walls and ceiling reaches the students with a long delay and interferes with the perception of the

primary sound. Students hear the primary sounds and the reflected sounds imultaneously, the words are distorted.

We measured the sound decay time: Standard reverberation time (1).

The greatest influence on the reverberation time is the sum of the sound absorption coefficients a of the sound-absorbing structures, the resonators.

After the sound is turned off, the reverberation in the room gradually weakens due to the absorption of sound by the sound-absorbing structures. The time it takes for the sound pressure level to drop by 60 dB is called the Standard Reverberation Time.

To determine the efficiency of the resonators, we first measure the Reverberation Time of the empty hall without resonators, and then the Reverberation Time of the hall with resonators.

If the Reverberation Time has decreased, then the resonators are efficient [12].

Conclusions

1. Multi-resonance acoustic structures designed for improving the acoustic environment of quality speech and music in halls, auditoriums, and recording studios have been developed.
2. Tests in the reverberation chamber and in real conditions in halls and recording studios have confirmed the high efficiency of multi-resonance acoustic structures.
3. It is advisable to use multi-resonance acoustic constructions for the reduction of low-frequency and infrasound noise in production buildings.
4. The content of the article can be used in "Green Construction", "Construction Acoustics", and "Architectural Acoustics" courses.

References

- [1] **Sam Kubba**, ISBN 978-0-12-385128-4 Handbook of Green Building Design and Construction, Imprint: Butterwourth-Heinemann, 2012, 820 p.
- [2] **Kuttruff, H.** Room Acoustics, 6th ed., CRC Press, 2016.
- [3] **Yan Ji and Stellios Plainiotis**, ISBN 7-112-08390-7 Design for Sustainability, Beijing: China Architecture and Building Press., 2006.
- [4] **D. Magliacano et al.** Numerical investigations about the sound transmission loss of a fuselage panel section with embedded periodic foams. Appl. Acoust.,2021.
- [5] **V.-S. Kim et al.** Double resonant porous structure backed by air cavity for low frequency sound absorption improvement. Compos. Struct., 2019.
- [6] **Л.А. Борисов, Б.Ю. Гаспарян, М.И. Могилевский**, Резонансный низкочастотный звукопоглотитель, Авторское свидетельство СССР N1291681, Зарегистрировано 22 окт. 1986 г., Москва, 4 с.
- [7] **Л.А. Борисов, Б.Ю. Гаспарян, Г.Л. Осипов**, Резонансный низкочастотный звукопозвукопоглотитель, Авторское свидетельство СССР N1296225, Зарегистрировано 30 нояб. 1986 г., Москва, 3 с.
- [8] **Л.А. Борисов, Б.Ю. Гаспарян, Ю.М. Чудинов**, Способ измерения характеристик звукопоглощающих конструкций, Авторское свидетельство СССР N1613874, Зарегистрировано 15 авг. 1990 г., Москва, 4 с.
- [9] **Л.А. Борисов, Б.Ю. Гаспарян, Ю.М. Чудинов**, Способ определения коэффициента звукопоглощения звукопоглощающих конструкций, Авторское свидетельство СССР N1682908, Зарегистрировано 07 окт. 1991 г., Москва, 4 с.
- [10] **ISO 354:2003.** *Acoustics – Measurement of soundt absorption in reverberation rooms.*
- [11] **Gustafsson, M., & Johansson, L.** (2017).”Reverberation and sound absorption in rooms.” *Buildind and Environment*, 115, 51-60.
- [12] **Kang, J., & Zhang,Y.** (2018). ”Noise Control in Buidings: A Guide to Acoustics and Soundproofing”. *Journal of Buildind Performance*, 9(2), 99-105.

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Բագրատ Յուրիի Գասպարյան

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Հոդվածում ներկայացված են դահլիճներում ակուստիկ հարմարավետության ապահովման անհրաժեշտ պահանջները: Աշխատանքը վերլուծում է դահլիճներում բազմակի արձագանքների վերացման նպատակով բազմառեզոնանս Ակուստիկ շինարարական կոնստրուկցիաների օգտագործման արդյունավետությունը: Ներկայացված են բազմառեզոնանս Ակուստիկ շինարարական կոնստրուկցիաների համակառուցի խմբի հետազոտման արդյունքներն իրական պայմաններում՝ Մոսկվա քաղաքի Դիմիտրովյան խճուղու վրա գտնվող Մոլոդեժնայա հյուրանոցի Գիտաժողովների դահլիճում և Երևանի Ալմաստ գործարանի արտադրամասում:

Բանալի բառեր. Հելմհոլցի ռեզոնատոր, բազմառեզոնանս Ակուստիկ շինարարական կոնստրուկցիաներ, հետարձագանքման խցիկ, հետարձագանքման ժամանակ, ձայնակլանման գործակից

РАЗРАБОТКА И ПРИМЕНЕНИЕ АКУСТИЧЕСКИХ СТРОИТЕЛЬНЫХ
КОНСТРУКЦИЙ В ЗАЛАХ

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В статье представлены необходимые требования для обеспечения акустического комфорта в залах. Работа анализирует эффективность использования многорезонансных акустических строительных конструкций для устранения многократного эха в залах. Представлены результаты исследования группы многорезонансных акустических строительных конструкций в реальных условиях: в зале конференций гостиницы Молодежная на Димитровском шоссе г. Москвы, и в производственном цеху завода Алмаз г. Еревана.

Ключевые слова: резонатор Гельмгольца, многорезонансные акустические строительные конструкции, реверберационная камера, время реверберации, коэффициент звукопоглощения

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