Investigation of Acoustic Impedance of a New Floor Panel Filling Generation

I Inzhutov\textsuperscript{1,}* , P Melnikov\textsuperscript{1}, S Amelchugov\textsuperscript{1}, V Zhadanov\textsuperscript{2} and V Purtov\textsuperscript{3}

\textsuperscript{1}Siberian Federal University, 660041, Krasnoyarsk, Svobodny Ave. 79, Russia
\textsuperscript{2}Orenburg State University, Orenburg, 460018, Victory Ave. 13, Russia
\textsuperscript{3}Novosibirsk State University of Architecture and Civil Engineering (Sibstrin), 630099, Novosibirsk, Russia

E-mail: *IInzhutov@sfu-kras.ru

Abstract. Acoustic comfort is one of the main factors of a man’s comfortable existence in the residence places. Over the past century, a lot of experience has been accumulated in isolating rooms from noise using enclosing structures, but the acoustic regime is deteriorating due to the constant increase in the power and number of noise sources in localities and buildings themselves. Therefore, acoustic comfort is not always provided in the premises even with satisfactory sound insulation of enclosing, as experimental studies have shown. In addition, humanity strives to build structures with the lowest material and labor costs. All this makes us look for more effective solutions for sound insulation and sound absorption. A sound-proof panel made of acoustic resonators ZIPAR is a plate of sound-absorbing material consisting of an outer sealed, sound-absorbing and sound-insulating layers. The air cavities of the sound-absorbing layer are made of upper parts-resonators, in the form of truncated cones, which cross-section decreases in the direction of the outer layer, and the cavities in the sound-absorbing layer have a cylindrical shape; these are the lower parts-deflectors. The data obtained as a result of tests are intended for use as a reference material in the design and installation of noise protection premises, both in new construction and in the reconstruction and minor repairs of existing buildings.

1. Introduction

The appearance of human auditory sensations is usually associated with air vibrations. Sound phenomena are a special case of wave motion. Mechanical vibrations of elastic environment particles in the frequency range from 16 to 20.000 Hz, affecting the human hearing organ, cause a sense of sound. Such vibrations are called sound vibrations, and the specified range is the frequency range of the audible sound. A sound is the subjective perception of these vibrations by special sensory organs of animals or humans [1-5].

The oscillated body causes the surrounding particles of the medium to oscillate at the same frequency. The state of oscillatory motion is successively transmitted to the medium particles that are remote from the body; a wave propagates in the medium with a frequency of oscillations equal to the frequency of its source at a certain speed depending on the density and elastic properties of the medium.

The sound speed depends on the density of the medium, which it is transmitted in. Sound waves can propagate in air, gases, liquids, and so lids. In an airless space (vacuum), waves do not occur. Sound waves in gases and liquids can only be longitudinal, since these media have elasticity only in...
relation to compression (stretching) deformations. In solids, sound waves can be both longitudinal and transverse, as well as surface, since solids have elasticity with respect to compression (stretching) and shear deformations.

It follows from [6] that the speed of longitudinal waves is in the range from 4.000 m/s to 7.000 m/s, and transverse waves - from 2.000 m/s to 3.500 m/s for most metals.

In different environments sound waves propagate at different speeds, which is a characteristic of a separate environment. The speed of sound propagation in the air depends on the air temperature and for normal conditions at 0° it is approximately 332.5 m/sec. In water, sound travels at a speed of 1.450 meters per second at zero temperature. As the temperature and salinity of the water increase, as well as the depth, and consequently, the hydrostatic pressure increase, the speed of sound increases.

Sound wave can be reflected and absorbed, encountering an obstacle (Figure 1). The energy of a sound wave, hitting a porous surface is partially reflected and partially dissipated. And the more pores in the material, the greater sound wave energy dispersion there. Materials that dissipate most of the energy inside themselves are called absorbing materials.

![Figure 1. Phenomena of reflection and absorption of sound waves.](image1)

Sound insulation of any structure, according to Noise protection. Updated version of BNR 23-03-2003 is characterized by two values: calculated air noise insulation index $R_w$ and actual air noise insulation index, $R'_w$. Both values indicate the difference in sound levels in front of and behind the enclosure (Figure 2). The difference is that the calculated index is determined in the laboratory and does not take into account the influence of floors, adjacent walls, etc.

![Figure 2. Air noise isolation.](image2)
Sound insulation is a set of measures aimed at achieving acoustic comfort. The ways to improve the efficiency of buildings’ sound insulation are associated with a whole range of passive and active measures. Passive measures are the most common in construction:

1. the use of massive enclosures (not always justified from a technical and economic point of view);
2. the use of multi-layer enclosing structures;
3. application of the air layer in the structure;
4. the use of sound-absorbing materials in the structure;
5. a device in the enclosure of grooves and protrusions in one of the structure’s layers;
6. an application of noise protection screens.

So, a hypothesis is formed that a system of resonators and deflectors has higher sound insulation performance, exposed to different sound frequencies than traditional sound-proofing materials.

2. Materials and Methods
We should confirm the facts, where the tests were conducted, which of sound phenomena, occurring in the test panel, were studied to establish the effectiveness of using this design as a modern sound insulation.

It is necessary to create a noiseless environment for conducting effective testing and obtaining accurate and stable results.

The acoustic plate design consists of 2 parts, 10×10 pieces of resonators (upper part) and deflectors (lower part). The thickness of ZIPAR panel is 230 mm, the wooden panel is 6 mm and the foam panel is 68 mm.

The space between the resonators and deflectors is filled with mounting foam in several steps until it is completely filled (Figures 4-5).

The connection between upper and lower parts of the panel is made using mounting foam (Figure 5).

![Figure 3. 10×10 structure of resonators and deflectors.](image)
3. Results
A subwoofer with speakers was installed at a distance of 30 sm from the structure. Sound waves with different frequencies were fed using an audio frequency generator.

The frequencies values applied to the structure, as well as the results, are summarized in Table 1. The first step is to set the noise level without a sound-proof plate. A plate is installed and tests are performed at the same frequency of sound waves. These noise level measurements are made for a set of audio frequencies. In order to compare the results, noise level measurements are performed for several cases: without sound insulation, ZIPAR panel, wooden panel, foam panel, combined version No.1 (wooden panel is installed on the deflectors, sound waves pass through the resonators), combined version No.2 (wooden panel is installed on top of the resonators, sound waves pass primarily through the wooden panel). All values set by the noise meter are entered in Table 1.

The tests were carried out using a structured system for studying and measuring the impedance, designed for sound pressure up to 10.000 Hz, consisting of:

Figure 4. Filling the space between resonators on the cut-off side with mounting foam (a model) a) front view, b) - view from the back side.

Figure 5. Acoustic panel after connecting two parts (a model).
On-line sound wave generator, which is operated via the phone;  
A phone;  
A subwoofer that reproduces low-frequency sounds (from 20 dB) and speakers;  
A sound level meter.

| Sound wave frequency, hz | without sound insulation | Zipar wooden panel | foam panel | combined variant No.1 | Combined variant No.2 |
|-------------------------|--------------------------|--------------------|-----------|-----------------------|----------------------|
| 1                       | 2                        | 3                  | 4         | 5                     | 6                    | 7                     |
| 20                      | 43                       | 38                 | 38        | 37                    | 34                   | 37                    |
| 30                      | 52                       | 48                 | 45        | 50                    | 47                   | 49                    |
| 40                      | 57                       | 50                 | 48        | 54                    | 50                   | 52                    |
| 50                      | 56                       | 51                 | 48        | 56                    | 52                   | 56                    |
| 60                      | 63                       | 55                 | 58        | 53                    | 59                   | 59                    |
| 70                      | 63                       | 57                 | 61        | 57                    |                      |                       |
| 80                      | 68                       | 63                 | 64        | 58                    | 62                   | 62                    |
| 90                      | 61                       | 57                 | 59        |                       |                      |                       |
| 100                     | 63                       | 59                 | 60        | 48                    | 48                   | 56                    |
| 110                     | 62                       | 56                 | 59        | 59                    | 59                   |                       |
| 120                     | 65                       | 57                 | 60        | 60                    | 60                   |                       |
| 130                     | 65                       | 57                 | 60        |                       | 60                   |                       |
| 140                     | 66                       | 60                 | 60        |                       | 60                   |                       |
| 150                     | 68                       | 62                 | 58        | 65                    | 65                   | 65                    |
| 160                     | 69                       | 64                 | 64        |                       | 64                   |                       |
| 170                     | 71                       | 65                 | 65        |                       |                       |                       |
| 180                     | 73                       | 64                 | 64        |                       |                       |                       |
| 190                     | 72                       | 64                 | 64        |                       |                       |                       |
| 200                     | 71                       | 63                 | 63        | 65                    | 65                   | 65                    |
| 250                     | 74                       | 70                 | 67        |                       |                       |                       |
| 300                     | 82                       | 75                 | 73        | 80                    | 76                   | 74                    |
| 350                     | 81                       | 70                 | 66        |                       |                       |                       |
| 400                     | 76                       | 70                 | 66        |                       |                       |                       |
| 450                     | 75                       | 71                 | 71        |                       |                       |                       |
| 500                     | 72                       | 66                 | 65        | 67                    | 67                   | 65                    |
| 550                     | 73                       | 65                 | 65        |                       | 65                   |                       |
| 600                     | 72                       | 64                 | 64        |                       |                       |                       |
| 700                     | 75                       | 60                 | 62        | 73                    | 73                   | 60                    |
| 800                     | 77                       | 62                 | 64        |                       |                       |                       |
| 900                     | 77                       | 64                 | 67        |                       |                       |                       |
| 1000                    | 77                       | 65                 | 65        | 67                    | 71                   | 66                    |
| 1100                    | 76                       | 71                 | 73        |                       |                       |                       |
| 1200                    | 79                       | 60                 | 60        |                       |                       |                       |
| 1400                    | 90                       | 60                 | 54        | 77                    | 80                   | 73                    |
| 1600                    | 85                       | 69                 | 71        |                       |                       |                       |
| 1800                    | 76                       | 59                 | 59        |                       |                       |                       |
| 2000                    | 74                       | 59                 | 59        |                       |                       |                       |
| 2500                    | 80                       | 63                 | 63        |                       |                       |                       |
| 3000                    | 86                       | 59                 | 59        |                       |                       |                       |
| 3500                    | 88                       | 66                 | 66        |                       |                       |                       |
| 4000                    | 88                       | 59                 | 66        | 70                    | 58                   | 56                    |
| 5000                    | 72                       | 65                 | 65        |                       |                       |                       |
| 6000                    | 83                       | 65                 | 65        |                       |                       |                       |
| 7000                    | 77                       | 59                 | 59        |                       |                       |                       |
| 8000                    | 86                       | 59                 | 59        |                       |                       |                       |
| 9000                    | 76                       | 59                 | 59        |                       |                       |                       |
| 10000                   | 82                       | 59                 | 62        | 71                    | 59                   | 61                    |
4. Discussion

Graphs (Figures 6-8), reflecting the influence of the sound-proof plate are constructed, according to the obtained data propagation of a sound.

![Graph 6](image)

**Figure 6.** Test results in the frequency range from 20 Hz to 10,000 Hz.

Starting with a frequency of 3.200 Hz and up to 8.000 Hz, the best indicators have combined options. From 8.000 Hz, the lowest noise levels are found in the combined version No.1.

![Graph 7](image)

**Figure 7.** Test results in the frequency range from 20 Hz to 500 Hz.

At low frequencies up to 500 Hz, all options work approximately the same.

![Graph 8](image)

**Figure 8.** Test results in the frequency range from 20 Hz to 10,000 Hz.
The Zipar acoustic panel better suppresses sound frequencies and reduces noise in the low frequency range from 1.000 Hz to 3.000 Hz.

5. Conclusion
Therefore, based on the research data result, we can conclude that the foam plate works the worst at frequencies up to 500 Hz. The values of the noise level are the closest to the noise level without any sound insulation. Indicators for other noise suppression options fluctuate very closely.

The range of sound frequencies from 1.000 Hz to 3,000 Hz includes sounds such as scratching with nails on wood, scrape of a metal sponge on dishes, creak of foam, noise of an electric saw, a woman's cry, a child's cry, scrape of a knife on a bottle, and so on. These sounds are unbearable for a person and become the strongest audio stimuli. Zipar acoustic panel best absorbs these sounds [7-12].

The wooden panel is second in terms of performance after ZIPAR panel in the range from 1.000 Hz to 3.000 Hz and also has good indicators for noise absorption. This means that their overall performance in noise suppression and sound wave reflection will be higher in the frequency range from 3.200 Hz to 8.000 Hz in a system with a ZIPAR panel, the best performance is provided by the combined version No.1 with the frequency range is from 8.000 to 10.000 Hz, where a wooden panel is installed on the deflectors, and sound waves pass through the resonators.

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