UDC 624.04+539.3

CONCRETE-RUBBER LAYERED STRUCTURES FOR THE PROTECTION OF BUILDINGS FROM VIBRATIONS AND SEISMIC IMPACTS

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Problem statement. Conventional building construction methods often leave structures vulnerable to damage from vibrations and seismic impacts. These events can cause significant structural stress, leading to costly repairs, safety hazards, and even building collapse. Therefore, there is a critical need for innovative and effective strategies to enhance the seismic resilience of buildings.

This research investigates the potential of concrete-rubber layered structures as a novel approach for mitigating the detrimental effects of vibrations and seismic events on buildings. The study aims to explore the effectiveness and feasibility of this layered design in absorbing and dissipating seismic energy, thereby reducing the structural burden experienced by the building during such events.

The purpose of the work. The application of metamaterials and heterogeneous structures for creating new types of vibration and seismic isolation of buildings and structures has been an actual research topic in recent years [1–3]. The presence of heterogeneous leads to complex dynamic effects, one of which is the formation of discrete frequency bands of pass and stop [4]. Thus, heterogeneous materials and structures can be used as wave filters, blocking the propagation of elastic waves in specified frequency ranges. This work is devoted to the development of layered structures for protecting buildings from seismic loads and vibrations.

Main part. The width of the band gaps increases with increasing contrast between the mechanical characteristics of the components. One of the promising solutions is to use combinations of concrete and rubber layers [1; 2]. The densities of concrete and solid rubber differ by about 2 times, while the difference between the elastic moduli of these materials reaches 10^5 times.

For given properties of the components, the band gap frequencies can be changed by varying the size l of the cell of the structure's periodicity. Thus, the first band gap is formed at $l = L/2$, where L is the wavelength [4]. Therefore, the lower the frequency of the wave that needs to be blocked, the larger the size of the periodicity cell and, accordingly, the thickness of the layers should be.

In this work, analytical solutions for the dispersion characteristics of layered structures were found using the Floquet-Bloch method [4]. Numerical simulation of the propagation of elastic wave processes was performed in the Ansys software package. The obtained analytical and numerical results are in good agreement with each other.

Two models of concrete-rubber structures were investigated, the characteristics of which are given in the table.

Model 1 is effective for vibration protection, providing maximum attenuation of elastic waves at a frequency of 50 Hz. Model 2 is proposed for protection against seismic loads. For its development, the seismogram of the earthquake in Oroville (California) in 1975 was used, the peak of destructive frequencies of which fell on the mark of 18 Hz [5].

Figures 1 and 2 show the signal energy attenuation levels depending on the frequency for models 1 and 2, respectively. The numbers near the curves indicate the number of periodicity cells.

Table

Characteristics of layered structures

Parameter	Model 1	Model 2
Concrete density, kg/m^3	2300	2300
Young's modulus of concrete, Pa	3.14×10^{10}	3.14×10^{10}
Concrete volume fraction	0.5	0.5
Rubber density, kg/m^3	1300	1300
Young's modulus of rubber, Pa	5.8×105	1.4×105
Rubber volume fraction	0.5	0.5
Width of the periodicity cell, m	0.3	0.4

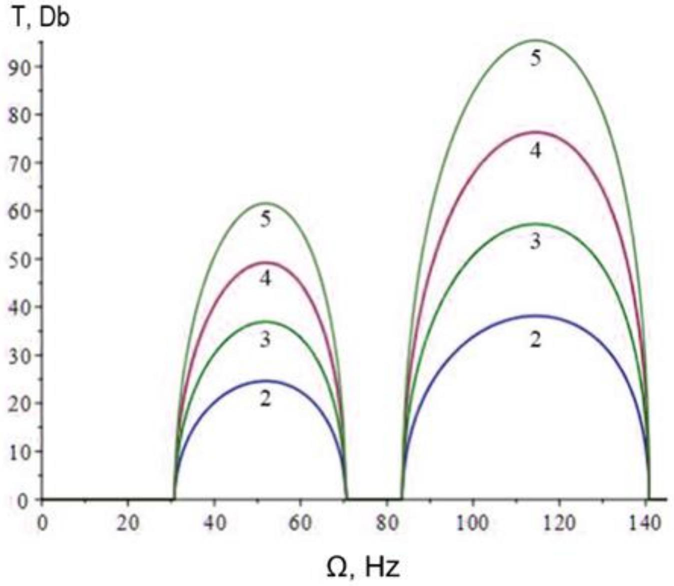

Fig. 1. Attenuation of elastic wave energy (Model 1)

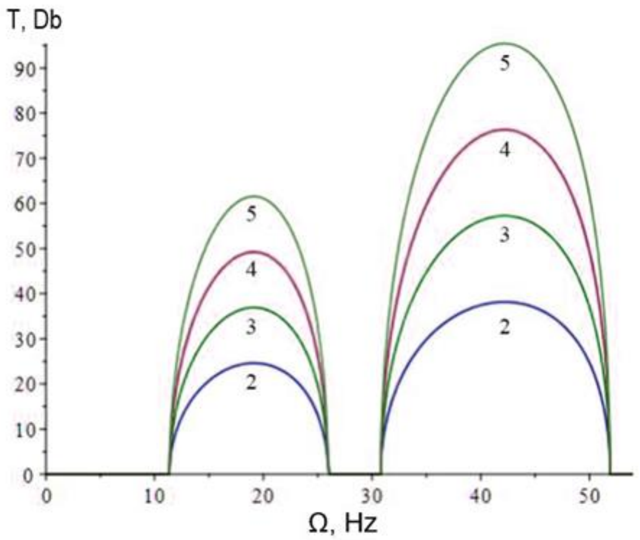

Fig. 2. Attenuation of elastic wave energy (Model 2)

Conclusion. It can be concluded that a layered structure with only five cells provides effective protection against dynamic effects, reducing the wave energy at the design frequency by 60 dB (10^6 times). The results of the work can be used to develop various types of heterogeneous materials and structures with pre-specified dynamic properties for protecting buildings and structures from seismic effects, vibrations, and creating effective acoustic insulation.

Acknowledgement. This work is supported by the European Commission under HORIZON 2020 project "A novel decentralized edge-enabled PREsCriptivE and ProacTive framework for increased energy efficiency and well-being in residential buildings", grant agreement ID: 958284.

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