Second Eurasian innovation forum «Current problems of development and safety of large cities»

The prospect of using geotechnical seismic insulation for the protection of architectural monuments

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2024

Introduction

Protection of architectural monuments from seismic impacts is one of the most important tasks in the field of cultural heritage protection. Historic buildings and structures, built over different eras and often using unique materials and designs, are vulnerable to the destructive effects of earthquakes. Every year there is a growing need to develop and implement effective methods that will preserve these valuable objects for future generations.

The use of geotechnical seismic insulation to protect architectural monuments is an effective method that allows you to preserve unique historical structures in conditions of seismic activity. Modern technologies and materials provide a high degree of protection and durability of such systems, which makes them an important tool in the field of cultural heritage protection.

The purpose of the article is to demonstrate the effectiveness and importance of geotechnical seismic insulation in the form of a mixture of soil and crumb rubber (rubber) for the preservation of architectural heritage, as well as to provide recommendations for the implementation of these technologies for the preservation of architectural monuments.

Materials and research methods

- To determine the effectiveness of geotechnical seismic insulation, a mixture of crumb rubber and soil (rubber grunt) was studied in Fig. 1. To determine the amplitudes of seismic impacts with and without geotechnical seismic isolation.

Figure 1. A mixture of crumb rubber and soil (rubber grunt)

Materials and research methods

- In the experiment, a standard compaction device PSU designed by SOYUZDORNII was used to compact soil, in which soil rubber was loaded into an assembled form. The experiment included the following stages:
- *Installation of equipment:* We prepared a base from containers of a larger diameter than the standard compaction device PSU designed by SOYUZDORNIA for soil compaction, into which soil was loaded (Fig. 2).

Figure 1. A mixture of crumb rubber and soil (rubber grunt)

Materials and research methods

- A BC 111 accelerometer was installed with the following parameters: built-in electronics of the ICP standard (IEPE), sensitivity 10 mV/g, frequency range 0.5-15000 Hz.
- *Creating a dynamic impact:* A load weighing 450 grams was thrown onto the surface of the ground models from a height of 25 cm to create pulse vibration.
- The BC 111 accelerometer recorded vibrations lasting 1 second and transmitted the data to a ZET 017-U8 spectrum analyzer with a dynamic range of 80 dB and a frequency range of up to 20 kHz.
- *Data collection and analysis:* The ZET 017-U8 spectrum analyzer was connected to a laptop in which the Zetlab software package was installed for collecting and analyzing data from the accelerometer (Fig. 3).

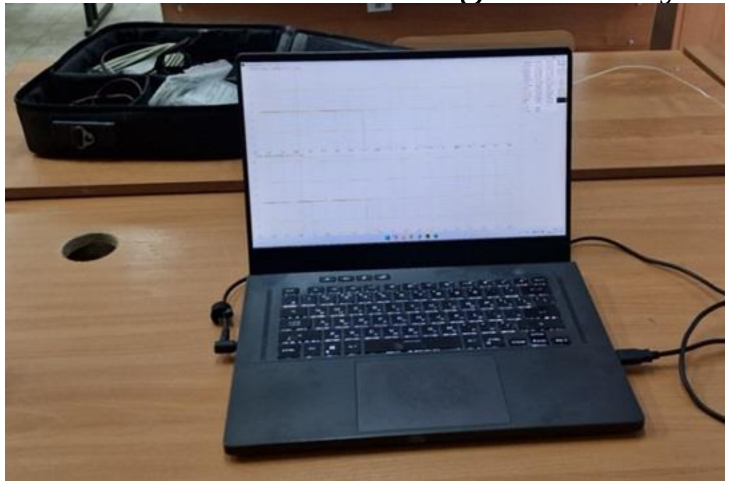
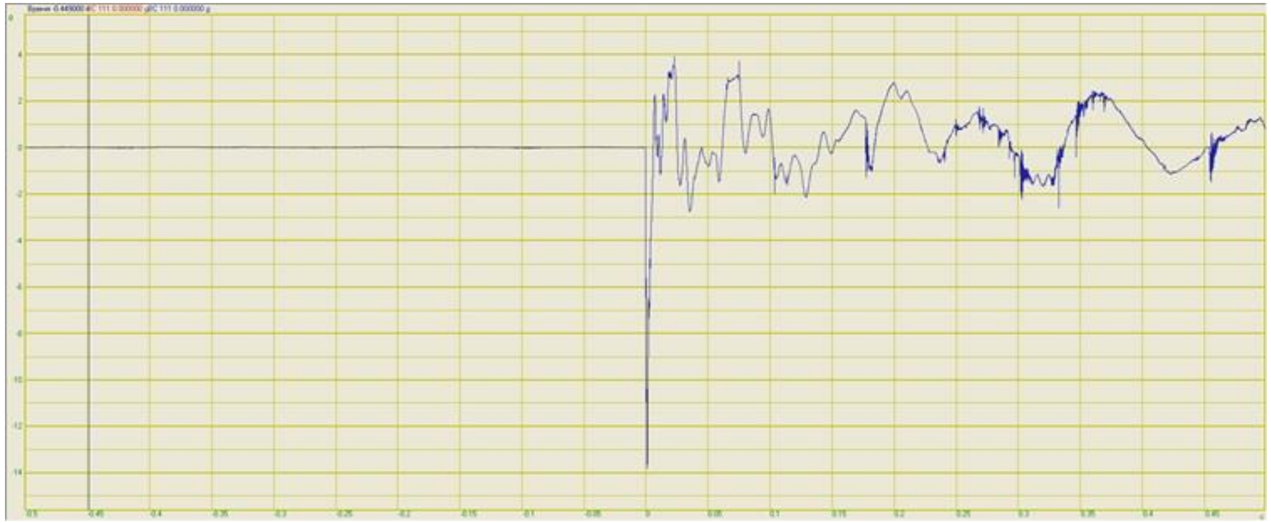


Figure 3. Laptop with Zetlab software package

Results and discussions

- Figures 4, 5 show the measured values of the amplitude of accelerations of soil rubber and natural (natural) soil without impurities. The amplitude of the ground wave without impurities shows a value of 13.85: the waves are not damped during the entire recording period of 0.5 seconds. Gruntorezina showed a decrease in amplitude and amounted to 8.75.



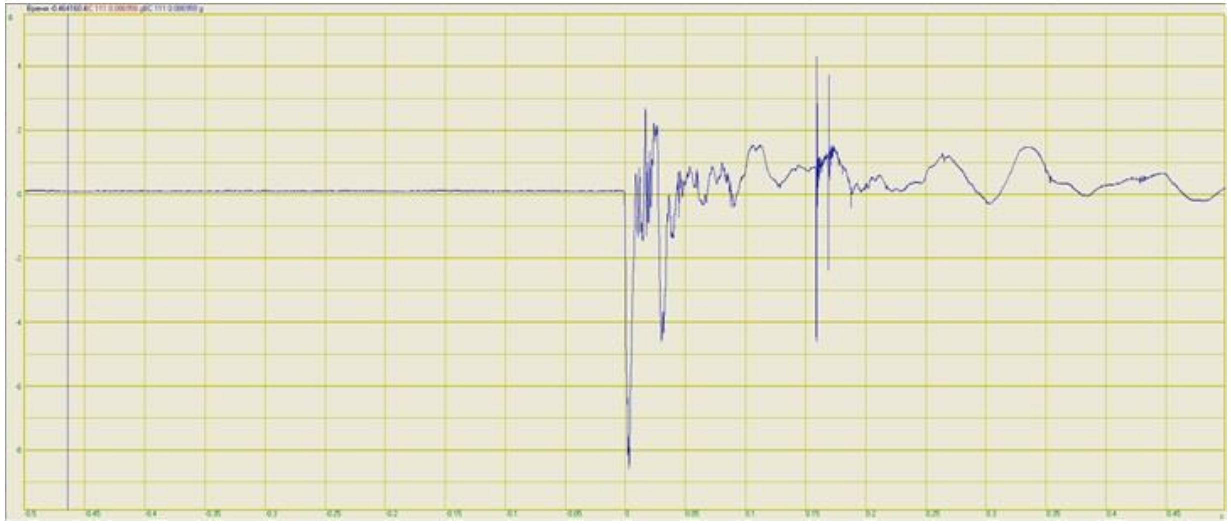


Figure 4. Accelelogram of natural soil

Figure 5. Accelelogram soil rubber

Results and discussions

• Analysis of the graph in Fig. 6 showed that soil rubber absorbs waves more effectively in comparison with natural soil. The average amplitude for soil rubber based on the results of 6 experiments was 8.75, while the amplitude for natural soil was 13.85.

• Based on the data obtained, we can conclude that soil rubber can be used to protect buildings, especially architectural monuments. In the future, based on these data, it is possible to develop effective seismic isolation methods .

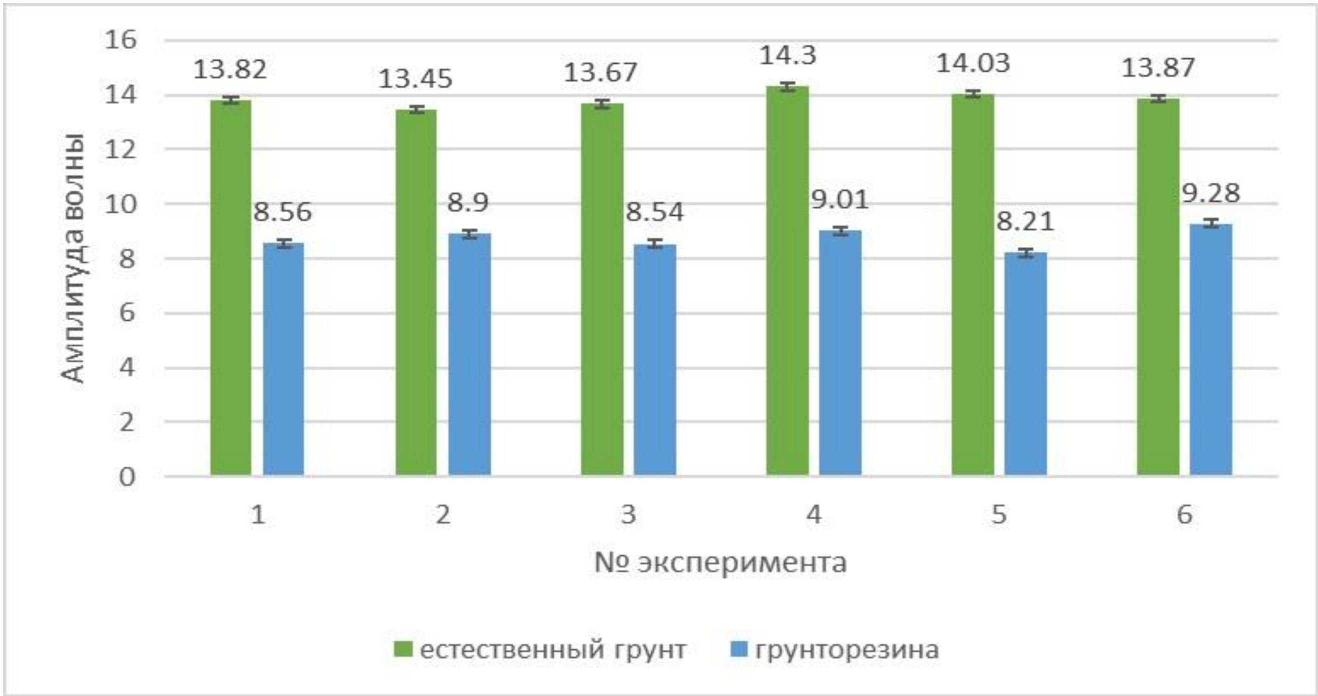


Figure 6. Vibration amplitude values of natural soil and soil rubber .

Conclusion

- To effectively protect architectural monuments, geotechnical seismic insulation made from soil rubber can be used. The results of experimental studies of the parametric characteristics of materials used as geotechnical seismic insulation showed excellent damping qualities.
- Rubber rubber in the form of geotechnical seismic insulation demonstrates a reduction in waves compared to soil without inclusions; the magnitude of the amplitude reduction is 36.83% compared to natural soil.
- Thus, reducing the amplitude of seismic vibrations leads to increased safety, durability and saving lives, making this technology important and useful for protecting buildings and infrastructure from seismic hazards, especially for the protection of architectural monuments.
- Geotechnical seismic insulation is a promising direction in earthquake-resistant construction, but its implementation requires an integrated approach that takes into account both technical and economic aspects, as well as the specifics of application in various geological conditions. Effective use of this technology is possible with careful planning and consideration of all factors affecting the functionality and durability of the system.

Bibliography

1. Forcellini , D.; Chiaro , G.; Palermo , A.; Banasiak , L.; Tsang , HH Energy Dissipation Efficiency of Geotechnical Seismic Isolation with Gravel Rubber Mixtures : Insights from FE Non- Linear Numerical Analysis // *Journal of Earthquake Engineering* 2024, doi:10.1080/13632469.2024.2312915.

2. Chiaro , G.; Palermo , A.; Banasiak , L.; Tasalloti , A.; Granello , G.; Hernandez , E. Seismic Response of Low-Rise Buildings with Eco-Rubber Geotechnical Seismic Isolation (ERGSI) Foundation System: Numerical Investigation // *Bulletin of Earthquake Engineering* 2023, *21* , doi:10.1007/s10518-022-01584-9.

3. Banović , I.; Radnić , J.; Grgić , N. Geotechnical Seismic Isolation System Based on Sliding Mechanism Using Stone Pebble Layer: Shake-Table Experiments // *Shock and Vibration* 2019, *2019* , doi:10.1155/2019/9346232.

4. Jing , L.; Yin , Z.; Sun, H.; Dong , R.; Xu , K.; Cheng , X. Shaking Table Test of Geotechnical Seismic Isolation System Based on Glass Bead-Sand Cushions // *Yanshilixue Yu Gongcheng Xuebao / Chinese Journal of Rock Mechanics and Engineering* 2020, *39* , doi:10.13722/j.cnki.jrme.2019.1138.

5. Pitilakis , D.; Anastasiadis , A.; Vratsikidis , A.; Kapouniaris , A. Configuration of a Gravel-Rubber Geotechnical Seismic Isolation System from Laboratory and Field Tests // *Soil Dynamics and Earthquake Engineering* 2024, *178* , doi:10.1016/j.soildyn.2024.108463.

6. Jing , L.P.; Yin , ZY; Sun, H.F.; Dong , R.; Xu , K.P.; Li,YQ Shaking Table Tests on Two Geotechnical Seismic Isolation Systems // *Yantu Gongcheng Xuebao / Chinese Journal of Geotechnical Engineering* 2020, *42* , doi:10.11779/CJGE202011001.

7. Dhanya , JS; Fouzul , M.A.; Banerjee , S.; Boominathan , A.; Zhussupbekov , A. Shaking Table Experiments on Framed Structure Resting on Geogrid Reinforced Geotechnical Seismic Isolation System // *Bulletin of Earthquake Engineering* 2023, *21* , doi:10.1007/s10518-023-01687-x.

8. Zhang , H.; Song , C.; Wang , M.; Cheng , Y.; Yue , S.; Wu , C. A Geotechnical Seismic Isolation System Based on Marine Sand Cushion for Attenuating Ground Shock Effect : Experimental Investigation // *Soil Dynamics and Earthquake Engineering* 2023, *168* , doi:10.1016/j.soildyn.2023.107854.

9. Sun, Q.; Xue , Y.; Hou , M. Geotechnical Seismic Isolation System to Protect Cut-and-Cover Utility Tunnels Using Tire-Derived Aggregates // *Soil Dynamics and Earthquake Engineering* 2024, *176* , doi:10.1016/j.soildyn.2023.108354.

10. Tsang , H. H.; Tran , D.P.; Hung , WY; Pitilakis , K.; Gad , EF Performance Geotechnical Seismic Isolation System Using Rubber-Soil Mixtures in Centrifuge Testing // *Earthq Eng Struct Dyn* 2021, *50* , doi:10.1002/eqe.3398.

Thank you for your attention!