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METHODS FOR CALCULATING BUILDINGS WITH SEISMIC INSULATION SYSTEMS

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Abstract. Currently, the main task facing modern seismically stable construction is the most effective and economically feasible tool for ensuring the reliability and seismic resistance of buildings and structures - a seismic isolation system. The task of reducing material and social damage from strong earthquakes is solved in two ways: developing earthquake forecasts and constructing earthquake-resistant buildings and structures. In seismic zones, the design of modern buildings and structures is carried out mainly in two directions - using passive and active methods[1-5]. The traditional (passive) method of ensuring the seismic stability of structures includes increasing the load-bearing capacity of structures by increasing the dimensions and strength of materials and the use of seismic belts, reinforced concrete additives in buildings with load-bearing brick walls, additional strengthening of the intersections of longitudinal and transverse walls, all of which require a significant increase in the number of building materials and equipment. The use of seismic insulation significantly increases the reliability of buildings; the safety and reliability of equipment, the economic indicators of buildings, the absence of the need for restoration work after strong earthquakes, creates convenience for the population.

Keywords: active method of seismic protection, seismic isolation, foundation, seismic impact calculation, seismic forces.

Introduction. The active method allows reducing seismic forces on the building by regulating the period and frequency of oscillations during the oscillation process during an earthquake. Regulation of dynamic parameters is carried out to prevent an increase in the resonance of building vibration amplitudes, at least to reduce the resonance effect. Numerous literature is devoted to the issues of calculating buildings with seismic isolation systems. These issues were considered in the articles and monographs of T.A. Belash [9], A.M. Uzdin, Yu.M. Aizenberg, I.O. Kuznetsova, O.A. Savinov, I.U. Albert, and other scientists **[7].** The issues of selecting calculation schemes for seismically insulated buildings have been studied quite deeply both in our country and abroad. In Russia, research in this area was conducted under the leadership of Professor O.A. Savinov and covered in the publications of T.A. Belash, A.A. Dolgaya, and other researchers. In the above-mentioned works, it was established that the simplest calculation schemes can be used for the analysis of seismic isolation, since the movement of the building is determined by the first form of vibrations, through which the building moves as a rigid whole due to the deformation of seismically insulated supports. This case is described in detail, in which 7 calculation schemes of a seismically insulated nuclear power plant are considered. It ranges from a single-mass system to a multi-mass system interacting with the soil, without taking into account the stiffness and damping of the foundation soil, which, in turn, is modeled by the finite element method. Among the less studied problems of modeling the operation of seismic isolation systems is the influence of the vertical component on the horizontal oscillations of the system. For kinematic supports, the vertical component leads to a periodic change in the oscillation period of the system, and the simple oscillation equations are transformed into the A.M. Maslennikov equations. However, research on the influence of the vertical component on seismic reactions is currently absent.

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The seismic isolation system consists of foundations made of various materials, for example, elastoplastic elements, the main type of which are rubber-metal supports (RMT). Currently, such seismic insulation elements are widely used in foreign countries. Elastoplastic supports are far from the shortcomings inherent in kinematic foundations, and their use is effective in the correct selection of the parameters of the seismic isolation system. One of the seismic isolation systems - rubber-metal supports installed between building foundations and load-bearing structures - is widespread in England, France, the USA, and New Zealand. The GAPES (France) supports consist of a multi-layered structure, consisting of a layered metal sheet-2 and neoprene-3. To prevent the building from sinking due to its own weight, the supports are made rigid in the vertical plane. Due to the elastic properties of polymers (neoprene, fluoroplastic, etc.), supports have high strength in compression, tension, and torsion. According to the authors, the service life of supports of this design is about 50 years. These seismic isolation supports were used in a three-story large-panel school building measuring 77.5 x 30.5 m in Lambesque (France) [10-15].

The established algorithm for modeling the acceleration of ground vibrations is expressed as follows:

$$\ddot{y}_{gr}(t)=A(t)\sigma u_m(t)$$

Here: $\ddot{y}_{gr}(t)$ – ground acceleration; $A(t)-$ vibration amplitude; σ - average acceleration value; $u_m(t)-$ modeling algorithm.

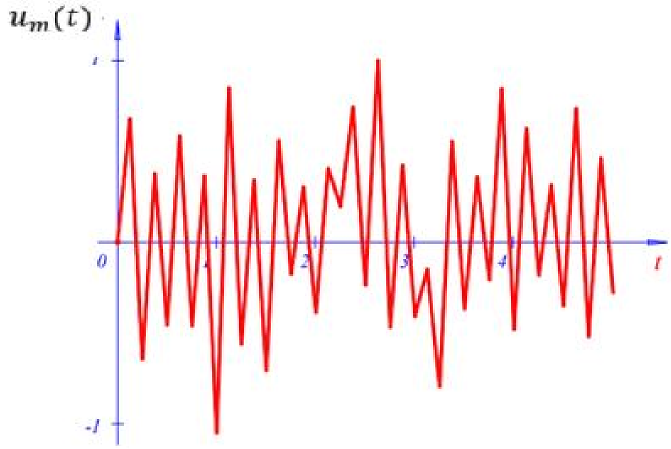

Figure 1. Algorithm for accelerating random earthquakes

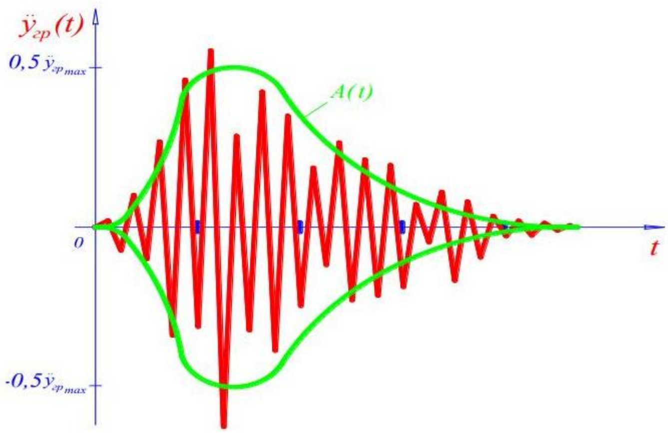

Figure 2. Algorithm for accelerating earthquakes modeled in the prescribed manner

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These supports reduce seismic accelerations by three to five times. The main advantages and disadvantages of solutions for seismic isolation of buildings using rubber-metal supports are:

Advantages of the system: The advantage of rubber-metal supports is the possibility of vertical forces, large horizontal shear deformations without loss of load-bearing capacity, which leads to a significant reduction in seismic forces.

Disadvantages of the system: The disadvantages of rubber-metal supports include the complexity of their manufacture (from a construction point of view), the placement of many supports under one building, and the sensitivity of the "building-support" system to low-frequency influences.

When forming initial data on seismic impacts, accelerograms are analyzed - a whole series of ground accelerations depending on time. For the selection of computational influences, instrumental recordings abroad were used in the same way as synthesized accelerograms in the country. Impacts were assessed according to two categories: intensity and frequency composition of the earthquake. The impact of an earthquake, measured in points, is determined using various scales. In Russia, the MSK-64 scale is commonly used. Therefore, after the digitization of more than 100 accelerorams, according to the MSK-64 scale, variants of influence corresponding to 7-9 points in intensity were considered. To increase the accuracy of the calculation results, the program allows changing the integration stage. Based on the program, the study of the seismic reaction of models of 9-story buildings with and without seismic isolation was carried out. At the same time, variants of buildings with seismic insulation using rubber metal and seismic insulation using the proposed fluoroplastic material were considered.

Seismic vibrations of the soil were established in the form of an artificial accelerogram with different oscillation periods with maximum acceleration corresponding to the seismic effect of the point. The seismic force was determined as follows:

$$S_i=m_i(\ddot{y}_i+\ddot{y}_{gr}) \quad i=1\div n \quad (2)$$

The elastic reactions of the calculated console model are determined as the product of the destruction of the layers with the stiffness coefficients of the system inside the layers.

$$K_i=k_i(y_i-y_{i-1}) \quad i=1\div n \quad (3)$$

The figure below shows the graphs of high mass movements over time.

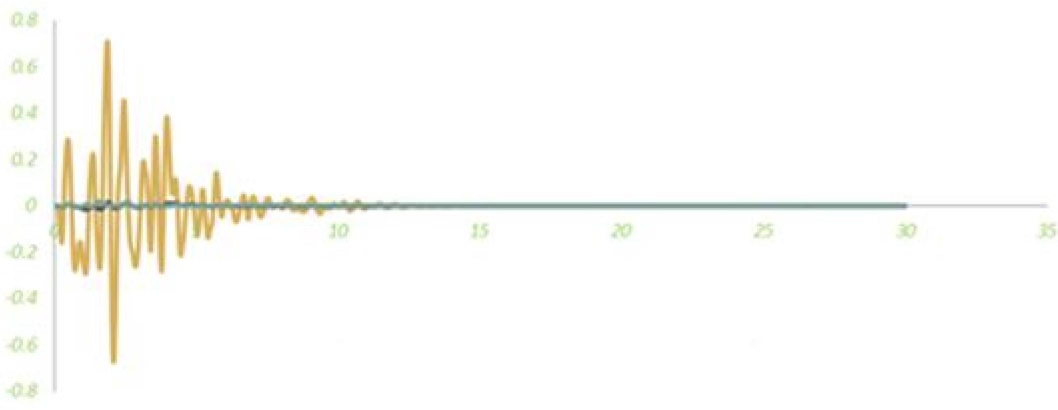

Figure 3. Graph of comparison of accelerograms reflecting oscillations of a model of a 9-story building, not seismically insulated, as well as seismically insulated (experimentally determined axologram) using a sliding belt.

As can be seen from the graphs, in the proposed 9-story building models, which are not seismically insulated and are seismically insulated using rubber-metal, displacements are significantly reduced.

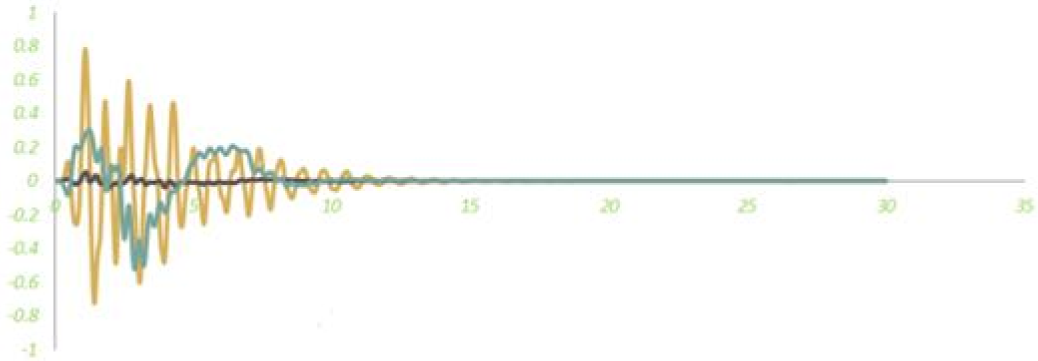

Figure 4. Graphs of the dependence of damage on the walls of a 9-story building duration of seismic impact.

Based on this graph, it was established that in frame buildings, the destruction of the foundation decreases from 2 to 4 times, in building walls - from 3 to 5 times, and in other structures - from 4 to 6 times. The distribution of inertial forces on the floors of the building at the moment of maximum seismic activity was determined as follows

Graphs of changing seismic forces on the floor of a building under the action of maximum horizontal movements are shown in the figure below.

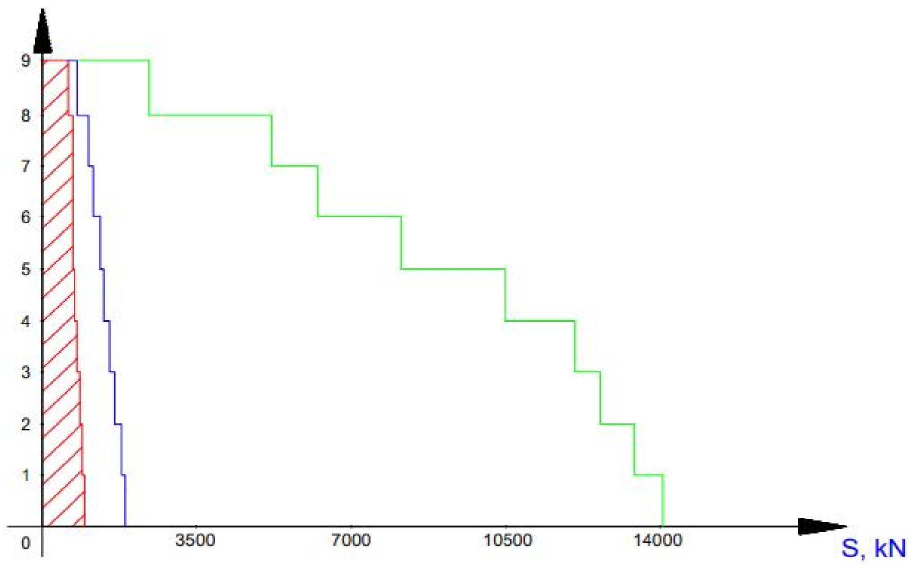

Figure 5. Graphs of maximum horizontal variable seismic forces

Analysis of these results shows that when comparing buildings not seismically insulated, seismically insulated with the help of rubber metal, and seismically insulated with the help of fluoroplastic, it reduces vibrations, failures in the building, ground inertial forces, and variable shear forces on the building floor by 1.35 to 2 times.

CONCLUSION: Based on conventional measures for seismic protection of buildings and structures, it is necessary to increase the load-bearing capacity of elements and structures. Such seismic protection is carried out in accordance with the construction rules "construction in seismic zones." In this case, the measures taken do not reduce seismic forces on buildings and structures, but only take them into account. When designing buildings and structures, in addition to spectral calculations of seismic insulation and dampers, it is necessary to perform dynamic calculations using instrumentally recorded accelerograms, which, in turn, increases the requirements for seismological forecasting for the construction site.

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