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Study of Earthquake Resistance of Buildings with Earthquick Foundations

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Abstract: A feature of the constructive solution of the building under study is the presence of a lower frame floor with switchable connections, which make it possible to change the rigidity of the lower tier by turning them off. The main structural elements of the adaptive seismic protection system were columns and buttresses. Switching elements are arranged between the heads of the upper and lower buttresses and are triggered when a certain level of movement of the lower tier of the building is reached. The work is devoted to the study of the dynamic behavior and seismic response of a building with switchable connections, in order to determine its rational dynamic characteristics.

Keywords: seismic insulation, seismic damping, seismic protection, damping, economic efficiency.

Based on the results of an analysis of the consequences of earthquakes in Mexico City, data on the performance of pile foundations during an earthquake were obtained [1]. Buildings on pile foundations turned out to be more stable, while many buildings on foundations in the form of reinforced concrete slabs were damaged. It was noted that with good quality workmanship, reinforced concrete piles ensure reliable operation of building structures.

During the Niigata earthquake, pile foundations showed high reliability; Not a single building on pile foundations was damaged, while buildings on conventional foundations received significant slopes. However, there were cases during earthquakes in Alaska when pile foundations, while ensuring the safety of overlying structures, themselves were damaged. Many experts paid attention to these facts, which led to the appearance of numerous studies.

Japanese scientists studied the interaction of a building with a pile foundation and the surrounding soil during an earthquake. The piles were 12 m long and rested on dense sand. Recording instruments were installed at different depths up to 24 m below the building. The authors note that the increase in the amplitudes of horizontal movement from the ground level to the top point of the building is 6.2 times in the transverse direction and 6.6 times in the longitudinal direction. Based on a comparison of the Fourier spectra for buildings and soil, the authors note that in the region of long-period components, both amplitudes are equal, and at the ground surface level, short-period components have a larger amplitude, although they have less influence on the building. Pile foundations, having increased damping during high-frequency vibrations, significantly reduce the corresponding vibrations of the surrounding soil and, thereby, help reduce seismic loads on building structures [1].

In [5], a self-defense system was investigated, including: reinforced concrete racks that absorb vertical loads from the weight of the building; rigid reinforced concrete buttresses that carry horizontal loads; switchable connections in the form of metal plates located between the upper and lower buttresses, as well as limit stops. Experimental and theoretical studies were carried out in order to identify the main patterns of seismic reactions of buildings with multi-stage disconnection of connections. An analysis of the behavior of a building equipped with a cascade system of switchable connections is made, taking into account their brittle and plastic destruction. The dependences obtained as a result of full-scale tests were used as deformation diagrams. A single-mass cantilever rod, rigidly clamped at the base, was adopted as a dynamic calculation model of the structure. As a result of the study, it was noted that in none of the cases of switching off the reserve elements was there a significant increase in the frequency and magnitude of the oscillation amplitudes. Destruction occurred only in the designated place. Based on the results of theoretical studies in [5], it is concluded that multi-stage and frame systems adapt well to seismic impacts with different spectral composition. The seismic response can be reduced by 3-10 times compared to a conventional building without switchable connections.

In [3], theoretical and experimental studies were carried out on a structural seismic protection system located between a rigid foundation and the grillage of the first floor of a large-panel house. The seismic protection system consisted of kinematic supports in the form of steel balls of switchable links and limit stops that prevent excessive horizontal and vertical movements. The work examines the dynamic behavior and seismic response of buildings equipped with a combined seismic protection system with switchable connections. The purpose of this study was to select rational dynamic characteristics and design solutions for a seismic protection system, taking into account the possibility of earthquakes with different spectral composition. An algorithm and program for calculating real accelerograms of structures with the seismic protection system under study have been developed. The program uses an experimental relationship between loads and displacements for kinematic supports.

The author of work [3] obtained the dependence of the seismic responses of the system under study on: a) the rigidity of the initial and final systems; b) geometric characteristics of supporting structures; c) the rigidity of the vibration limiter stop; d) the size of the gap between the system and the stops; e) the load level corresponding to the disconnection of connections, as well as the spectral composition of the expected impacts.

Five-story residential buildings were investigated in a 9-point seismic zone [2[. The above-ground part of the building was a spatial multi-connected box-shaped system of an open profile, consisting of a set of transverse and longitudinal load-bearing walls with a pitch of 3x3.6 m and longitudinal ones with a pitch of 2.4 m. A feature of the design solution of the building under study is the presence of a lower frame floor with switchable connections, which make it possible to change the rigidity of the lower tier by turning them off. The main structural elements of the adaptive seismic protection system were columns and buttresses. Switching elements are arranged between the heads of the upper and lower buttresses and are triggered when a certain level of movement of the lower tier of the building is reached. The work is devoted to the study of the dynamic behavior and seismic response of a building with switchable connections, in order to determine its rational dynamic characteristics. A console with three masses, rigidly clamped at the base, was used as a calculation model of the structure. The studies have shown that the maximum values of the elastic restoring force in systems with disconnected connections are 1.4-2.3 times lower than in conventional systems when the disconnected connections are located in the first tier, and 1.2-2 times in the second.

In [4], the dynamic parameters of an experimental, real building with a flexible first floor with inelastic switching connections were studied. Brackets were welded to the embedded parts of the stiffening diaphragm and the crossbars of the first floor to install inelastic release links in them. The dynamic tests carried out showed the possibility of changing the rigidity and, consequently, the frequencies of natural vibrations over a wide range. An algorithm and program for calculating a model of a building equipped with a cascade adaptive seismic protection system with inelastic release connections were developed. It has been revealed that the seismic protection system of structures with cascaded inelastic release connections leads to a significant reduction in seismic movements, in comparison with the movements of systems with elastic-brittle connections, depending on the spectral and other characteristics of the predicted seismic impacts.

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