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Selection of Geometric Dimensions of Active Seismic Protection of Buildings

Juraev Bahtiyor Gulomovich

A senior teacher, Department of Construction of buildings and structures, Namangan Engineering Construction Institute

ABSTRACT: Kinematic supports of earthquake-resistant buildings with geometrically little changeable structure of support structures are considered; supports have a complex end surface and help limit seismic loads on buildings.

KEYWORDS: seismic isolation system, kinematic supports, elastic-nonlinear force-displacement relationship, differential equation of motion, seismic response of a single-mass seismic isolation system, multi-storey buildings with kinematic foundations, non-stationary random process, statistical test method, seismic loads, floor imbalances

I. INTRODUCTION

One of the most important national economic tasks is to increase the efficiency of capital investments based on the use of the achievements of scientific and technological progress and a further increase in the volume of construction of buildings and structures in Uzbekistan, including in areas in the zone of increased seismic hazard. In this regard, additional costs for anti-seismic measures increase, which, on average, with a seismicity of 9 points - 9-15%, 8 points - 6-8% and 7 points.

In the CIS and abroad, in recent years, seismic isolation systems, called systems with kinematic supports, have been spreading.

Kinematic supports used for seismic isolation of buildings consist of ellipsoids of revolution or posts with spherical end surfaces, they are located between the foundations and above-ground structures of buildings. Moreover, these supports are placed, as a rule, at the intersection of longitudinal and transverse walls. Each support has two spherical surfaces, so rolling friction is created between the foundation and the above-ground structures. With their high-quality manufacturing and installation, the magnitude of the seismic load and, accordingly, the efforts in the bearing structures of buildings are significantly reduced.

Experts have developed and proposed three types of gravitational seismic isolation system, and then introduced into the practice of housing construction in the city of Sevastopol. The working elements of these systems are ellipsoids of revolution (spheroids), spherical racks: for the first building - cement-sand (height 56 mm with spheres with a radius of 30 mm); for the second - reinforced concrete (height 425 mm with spheres with a radius of 250 mm); for the third - reinforced concrete (height 3450 mm with spheres with a radius of 3450 mm). Full-scale static and vibration tests of five-floor buildings on spheroids with dry friction and an eight-floor large-block building with spherical struts and with multistage inclusion of dissipative forces of dry friction, erected in Sevastopol

Kazakh specialists carry out systematic studies of buildings with a kinematic foundation. A distinctive feature of the system is the device at the level of the feed or basement floor of special columnar foundations with two spherical surfaces with different radii. Due to the rotation of the foundations during seismic action, there is a smooth change in the main period of natural oscillations of the building and detuning from the resonance mode during forced oscillations. The system is also equipped with additional damping elements. Based on the results of laboratory tests, projects of a four-floorbuilding of the 1-464-UM series on a kinematic foundation were developed. Construction was carried out and full-scale static and vibration tests of a four-story building built in the city of Navoi were carried out.

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II. MATERIALS AND METHODS

The aim of the study is to obtain formulas for calculating the probabilistic characteristics of the seismic response of a nonlinear seismic isolation system with a given force-displacement function, characteristic of a seismic isolation system with kinematic supports, and to evaluate the effectiveness of this seismic isolation system in multi-floor buildings. The studies were carried out by analytical methods and by the numerical method of statistical tests. Analytical expressions for calculating the root-mean-square value of displacement of a single-mass seismic isolation system with kinematic supports and graphs of the effectiveness of using kinematic supports for seismic isolation of multi-floor buildings, compiled from the results of numerical experiments by the method of statistical tests, are obtained. The use of kinematic supports, with the force-displacement relationship described by a nonlinear function specified in the work, allows to reduce seismic loads on buildings and floor distortions by 2 or more times. Kinematic foundations are more effective for high-frequency influences and in buildings of a constructive solution with a height of no more than 5 floors.[5-14]

The question of the optimal design of the elements of the kinematic foundation is one of the main objectives of this work. To solve this problem, it is necessary to select their elements in such a way that the seismic load of buildings and structures is reduced to the maximum while ensuring the conditions of strength, stability and reliable operation of the seismic isolation system. [8]

The main results in the selection of the geometric dimensions of the spheroids of revolution were obtained after solving the equation of motion of the system on the seismic effects of El-Centro and Spitak.

Research is devoted to the optimal design of buildings and structures during seismic effects [1, 2, 4, 5, 7].

In these works, various criteria of optimality are accepted: minimum cost, uniform strength, uniform distribution of the coefficient of compliance, uniform distribution of the coefficient, etc. The adoption of a particular criterion in each particular case leads to the definition of a rational construction. However, it should be noted that the adoption of such different criteria of optimality is not dictated by the fundamental need, but only due to the convenience of solving a particular task. For some types of buildings and structures, it may be required that the work of the material of the structure occurs in the elastic stage and does not have any damage, and in others, it is possible that a certain level of residual deformations and local damages are allowed. In this paper, the optimality criterion for determining the geometrical parameters of the kinematic foundation is the maximum seismic load reduction.

To solve this problem, it is necessary to proceed from the result of the calculation of buildings with seismic protection elements, taking into account the linear and nonlinear works of the kinematic foundation.

In this study, we consider the results of the calculation of buildings, taking into account the linear nature of the seismic protection system. This can be explained by the following circumstances.

Firstly, the applicability of linear seismic protection system means that it becomes possible to use an analytical solution of the differential equations of motion. Secondly, after solving the problem of optimal design in a linear formulation, it is possible to compare the results with nonlinear statements by using the approximation coefficient of the “restoring force-displacement” dependence, which are an integral part of the nonlinear equations of motion.

III. RESULTS AND DISCUSSION

In this research, the results of numerical analysis of the studied 5-storey large-panel building with kinematic supports with a period of natural oscillations T = 0.3 s [6] and mass M=22640 kN are presented.

External influences are given by accelerograms of El-Centro SJ earthquakes, 1940. and Gukasyan SJ, 1988 normalized by a maximum acceleration of 0.4 g, which corresponds to intensity 9 seismicity of the construction site [3].

As a result of numerical analysis, the value of the maximum seismic response of the investigated building, depending on various geometrical parameters *r*, *h*, and *R* of kinematic foundations is shown in the graphs (Fig. 1-3). The minimum

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value of the seismic response was obtained in points with values r = 10.11 cm, h = 5 cm, R = 15 cm; r = 16, 17, 18 cm, h = 7, 8, 9 cm, R = 22 cm; h = 32, 36 cm, R = 66 cm; r = 180 cm, h = 140 cm, R = 200 cm; r_1 = 12 cm; r_2 = 15 cm, h_1 = 6 cm, h_2 = 10 cm, R = 22 cm.

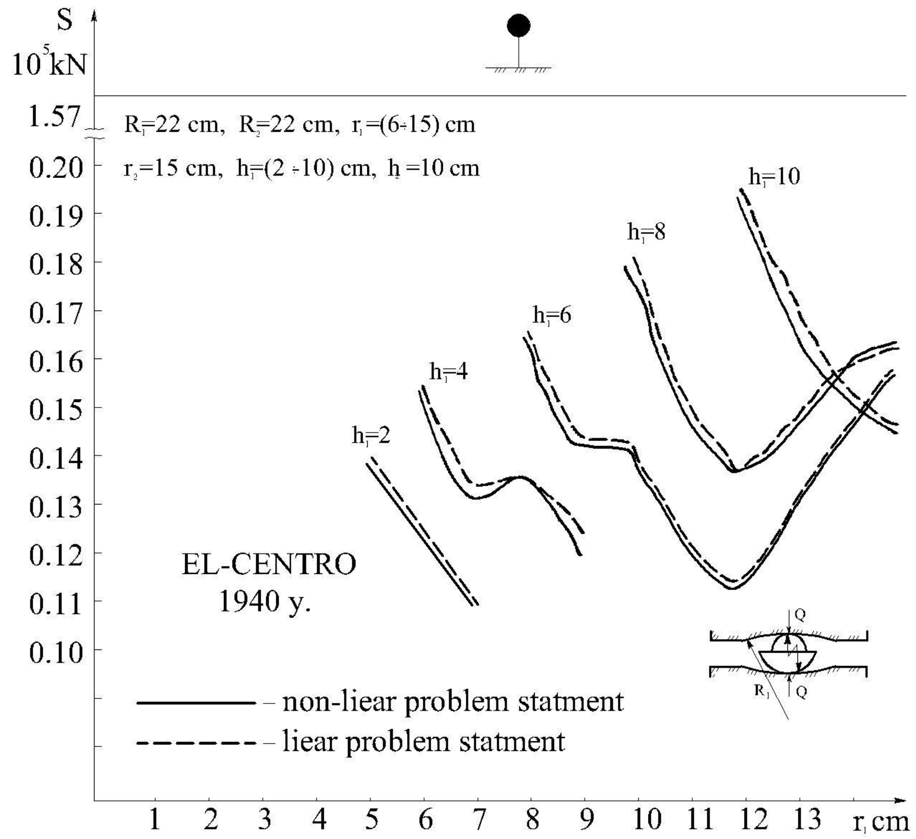

Fig.1 Spector seismic response of buildings in the first variant at R=66 cm

It should be emphasized that these kinematic parameters characterize the work of the building during the whole process of seismic impact and manifest themselves at different points in time.

The calculation results presented in the figures show a significant decrease in the maximum seismic response (3-10 times), which corresponds to a decrease in the estimated seismicity of intensity 1–3 when compared with the seismic response tasks of the missing seismic protection elements.

A more detailed study of the influence of types of kinematic supports on the parameters of the seismic response revealed the following features. At certain values of *h* and *R* and a gradual increase in *r* conducts to a certain periodic increase, the maximum seismic response of buildings. But for minimum values of forces, the ranges of stable values are increased.

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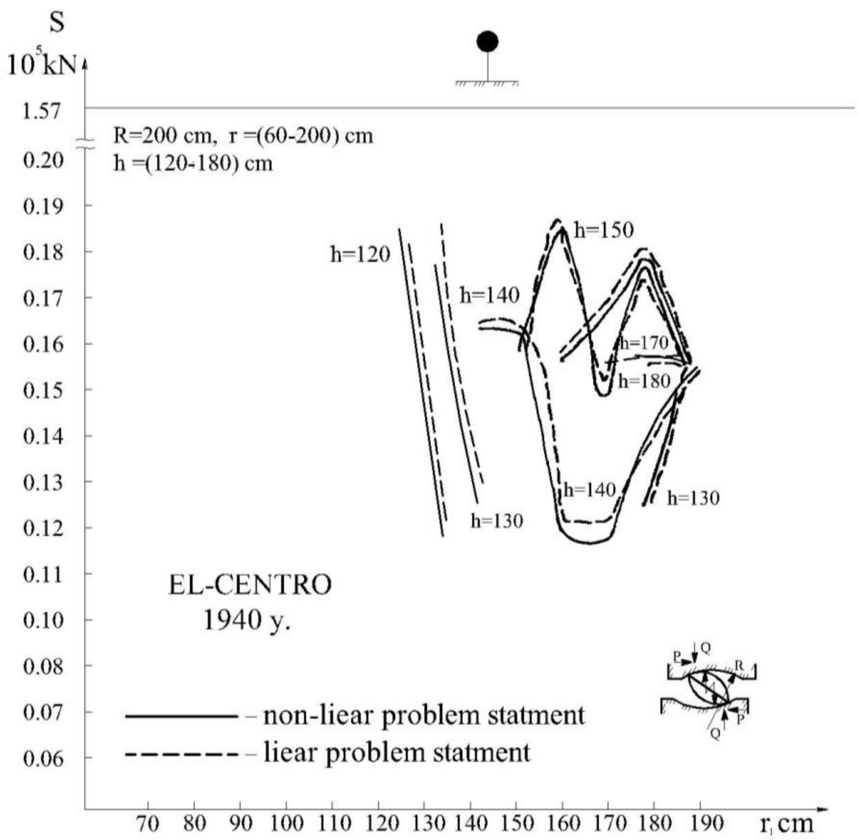

Fig.2 Spector seismic response of buildings in the second variant option at R=200 cm.

When comparing the results for the same geometrical parameters of the KF (kinematic foundations), it was shown that buildings equipped with seismic protection elements 3rd variant more effective (Fig. 2), since the seismic force has the lowest value at $r_1=12$ *cm*, $r_2=15$ *cm*, $h_1=6$ *cm*, $h_2=10$ *cm*, $R=22$ *cm.*

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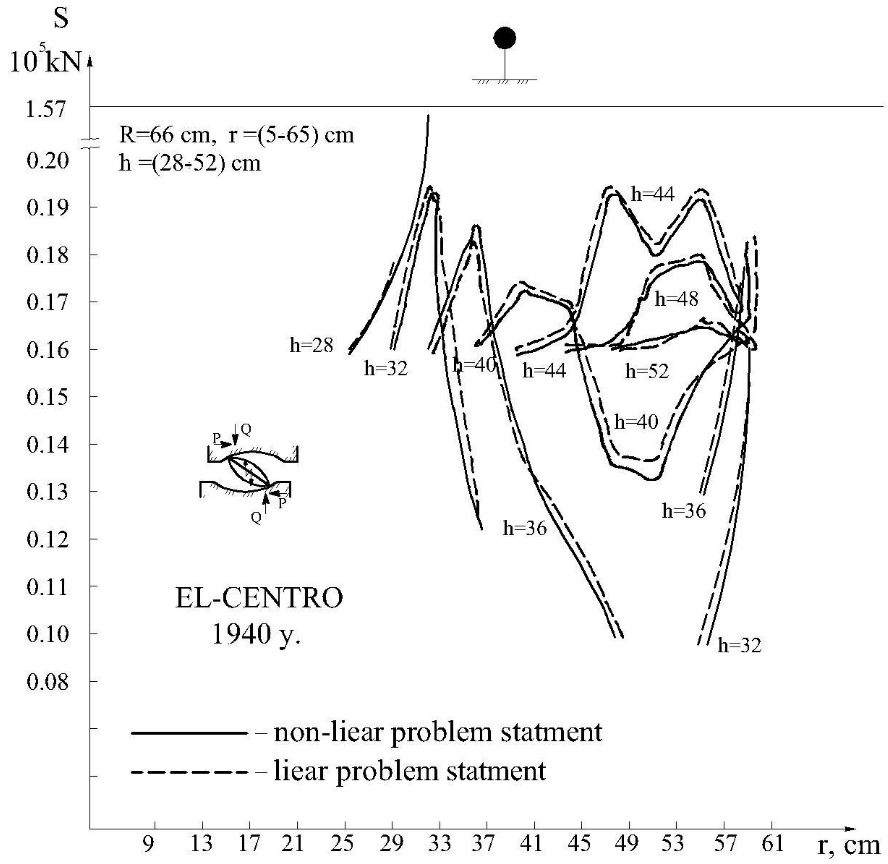

Fig.3 Spector seismic response of buildings in the fourth variant at R=22 cm.

In the calculation performed, the first and second lines are considered. The obtained graphs show that the difference from linear and nonlinear problem statements is 10-15% of the seismic loads in one mass building on kinematic supports.

III. CONCLUSION

The results of the computational studies of large-panel buildings with a seismic insulating kinematic foundation indicate a significant reduction in seismic loads on above-ground structures of buildings, the effectiveness of using kinematic supports and the prospects of such seismic protection systems for construction in areas with high seismic activity of intensity 8 and 9.

In general, based on the results of the above numerical analysis, it can be concluded that the inertial loads are significantly reduced for the large-panel building under study with a seismic protection system, as well as about the effectiveness of using various types of kinematic foundations with an appropriate selection of their geometric parameters and design.

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