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THE APPLICATION OF THE METHODS OF SPECIAL SEISMIC PROTECTION [142]

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Abstract: *The paper reviews existing methods of special seismic protection and shows the necessity to use them in the high-rise frame structures. Special attention was paid to the dynamic isolation systems. The purpose was to research the efficiency of rubber isolation bearings and pile foundations with an "intermediate cushion" and to demonstrate the commercial benefits of the special seismic protection. Structural analysis was carried out by a spectral method by means of program SCAD. On the basis of the results was achieved a numerical solution of the problem for a simplified model and for a real 5-storey building.*

Keywords: *Special Seismic Protection, Model, Dynamic Isolation Systems, Rubber Isolation Bearings.*

INTRODUCTION

There are many kinds of seismic protection in the field of civil engineering: kinematic foundations, sliding girdle with fluoroplastic for earthquake-proof building, the protecting trench around a building, earthquake-proof buildings, flexible ground floor, rubber isolation bearings [1], [3], [10]. Seismic forces are directly proportional to the mass of the building and reach their maximum value while resonant vibrations of the system "building-foundation". Non-traditional methods of isolating the structure from its foundation enable an isolated part of the building to vibrate at a frequency which is different from the frequency of the base (non-isolated) part of the building. Then the phenomenon of resonance of the system "building-foundation" does not occur and seismic forces do not reach their maximum value. Thus, special earthquake protection fights with the causes of the dynamic load - seismic forces produced by the system "building-foundation" [5].

1. INVESTIGATION OF DAMPING BEARINGS USING A SIMPLIFIED MODEL

A five-meter rod was used as a simplified model (Fig. 1). It was divided into five equal parts. The rod has a square cross section of 400 mm by 400 mm. It was made of concrete (class B25) [4].

Five concentrated masses were applied to the points of the rod (points 2-6). Ten calculations were made using program SCAD. All these ten simplified models had different horizontal stiffness of a damping bearing, K (0; 0,6 t/m; 1 t/m; 5 t /m; 10 t/m; 15 t/m; 20 t/m; 30 t/m; 40 t/m; 50 t/m). As a result of the calculation horizontal displacements (u) of the bottom point of the rod (Fig. 2), bending moments in the rod (M) and seismic forces (Fig. 3) for the points 2-6 of the rod were obtained. Calculation of seismic forces was determined by the formula:

$$S_{0ik} = Q_k \times A \times \beta_i \times \eta_{ik} \times K_\psi \qquad (1)$$

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Q_k - the mass of the building in point k; A, β_i , K_ψ, η_{ik} – coefficients enacted according to literature source [7], [8].

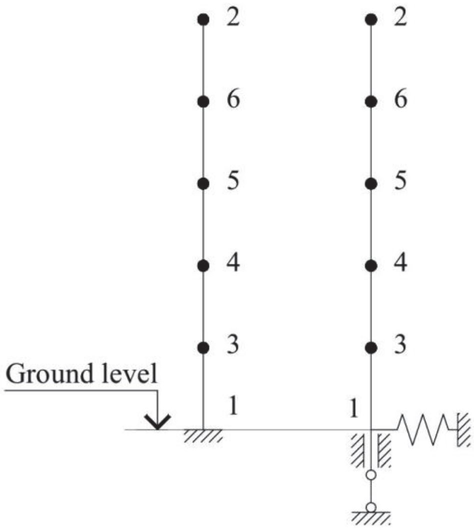

Fig. 1. A rod with a damping bearing (left). A rod with a rigid fixed bearing (right).

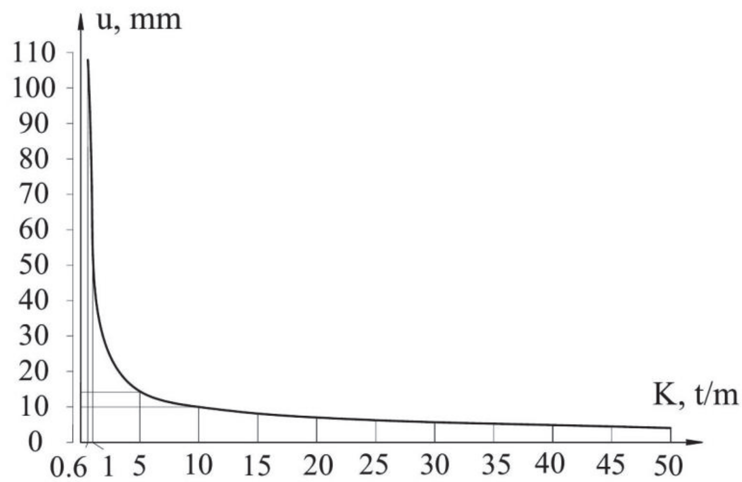

Fig. 2. The relationship between the stiffness of a damping bearing (K) and the horizontal displacement of the bottom point of the rod (u)

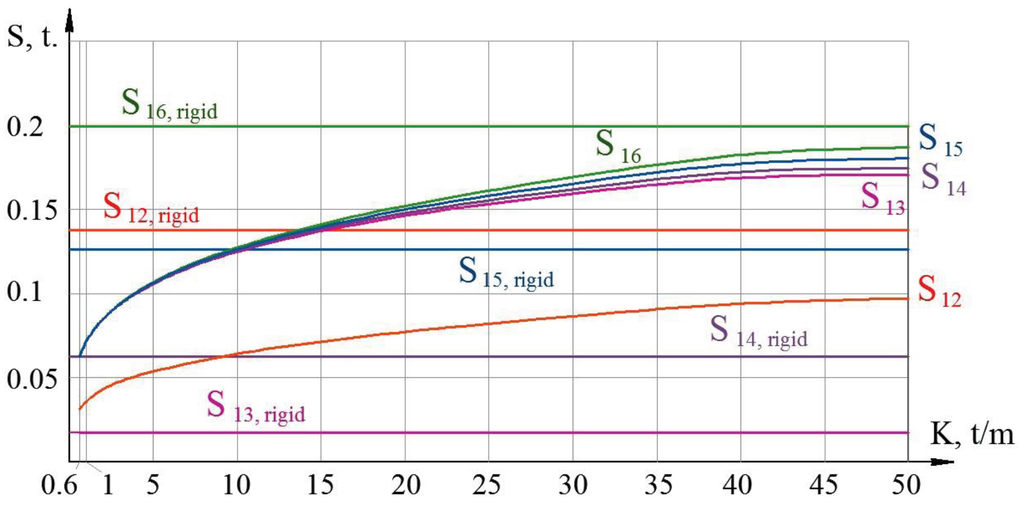

Fig. 3. The relationship between seismic forces (the first mode of vibration) (S_{1i}) and the stiffness of a damping bearing (K)

- in the range from K=0.6 t/m to K =50 t/m (Fig. 3) seismic forces of the two top points of the rod S_{12} and S_{16} in the case of a damping bearing are smaller than seismic forces $S_{12,rigid}$, $S_{16,rigid}$ in the case of a rigid fixed bearing

- In the beginning of the investigated range (Fig. 3) seismic forces of two points of the rod S_{15} and S_{14} do not exceed seismic forces $S_{15, rigid}$, and $S_{14, rigid}$. During the rage from K=0.6 t/m to K=50 t/m seismic forces S_{15} and S_{14} grow steadily. In the end of the investigated range seismic forces of two points of the rod S_{15} and S_{14} exceed seismic forces $S_{15, rigid}$ and $S_{14, rigid}$.

- in the range from K=0.6 t/m to K =50 t/m (Fig. 3) seismic forces of the bottom point of the rod S_{13} in the case of a damping bearing exceed seismic force $S_{13, rigid}$ in the case of a rigid fixed bearing. Thus, Fig. 3 clearly demonstrates that there is the phenomenon of redistribution of seismic forces.

2. INVESTIGATION OF A FIVE-STOREY FRAME BUILDING

To estimate the change in bending moments a new concept ε was introduced. It was called "share of efficiency (ε)"

$$\varepsilon(K) = \frac{M_0 - M_{K=Ko}}{M_0} = \frac{\Delta M}{M_0} \tag{2}$$

M_0 - the bending moment in the element with a rigid fixed bearing; M_K - the bending moment in the element with a damping bearing. ΔM - the difference between bending moments.

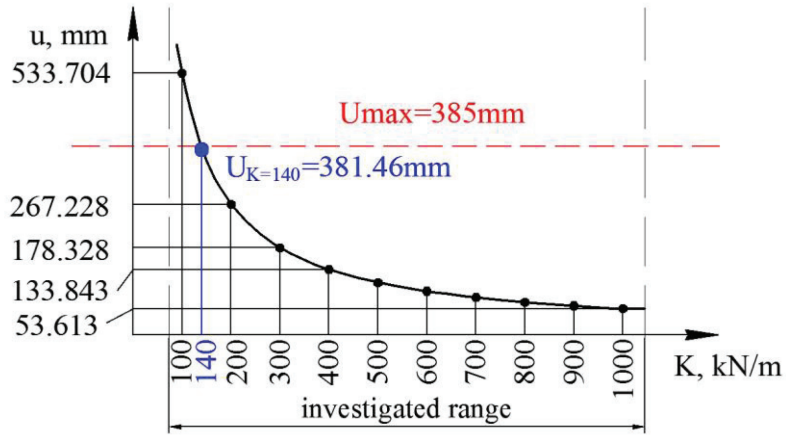

Fig. 4. The relationship between the stiffness of a damping bearing (K) and the horizontal displacement of the bottom point of the building (u) in the range from K=100kN/m to K =1000 kN/m

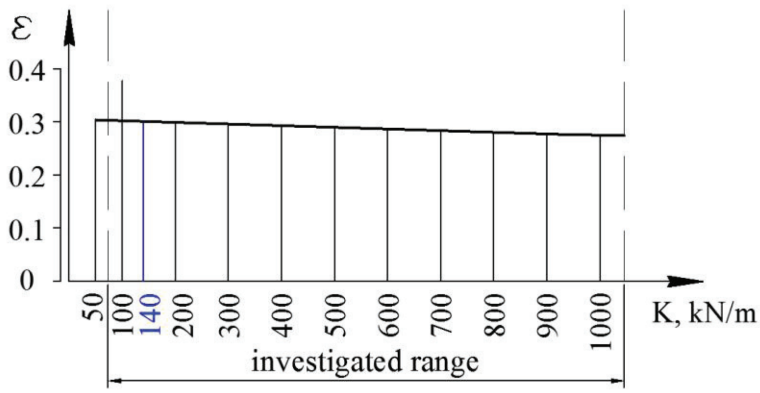

Fig. 5. The relationship between the stiffness of a damping bearing (K) and the share of efficiency (ε) in the range from K=100kN/m to K =1000 kN/m

Permissible horizontal displacement of the bottom point of the building umax = 385mm [3]. Fig. 4 demonstrates how to obtain "permissible" horizontal stiffness of the damping bearing

K_{max} = 140 kN/m. This value can be established as the optimal stiffness K. Using Fig. 5 it is possible to observe that the value of "the share of efficiency" at the optimal stiffness K is a little less than 30%.

3. INVESTIGATION OF A FIVE-STOREY FRAME BUILDING WITH LOAD-BEARING WALLS

Structural analysis five-storey frame building with load-bearing walls was carried out by a spectral method by means of program SCAD (magnitude 8 dynamic loading) [6].

The analysis of the calculation:

All internal forces (bending moment M and longitudinal force N) in linear elements of the building are extremely small compared to the internal forces caused by static loading. The use of dampers in the five-storey frame building with load-bearing walls is inappropriate.

4. INVESTIGATION OF A FIVE-STOREY FRAME BUILDING WITH AN "INTERMEDIATE CUSHION"

Horizontal stiffness (K) of an "intermediate cushion" is determined by its composition (sand and gravel), density, thickness. Varying composition, density, thickness it is possible to change elastic modulus (E) and Poisson's ratio (ν) of the "intermediate cushion" [9]. Table 1 shows numerical results of these investigations.

Table 1. Share of efficiency (ε) for the elements of the building

№	Type of foundation	Share of efficiency (ε) for beams	Share of efficiency (ε) for columns
1	"bush" pile foundation	0,209241	0,233306
2	strip pile foundation	0,122318	0,145833
3	"field" pile foundation	0,118119	0,142239

5. INVESTIGATION OF THE EFFICIENCY OF THE APPLICATION OF THE DAMPING BEARING FOR BUILDINGS OF DIFFERENT NUMBER OF STOREYS

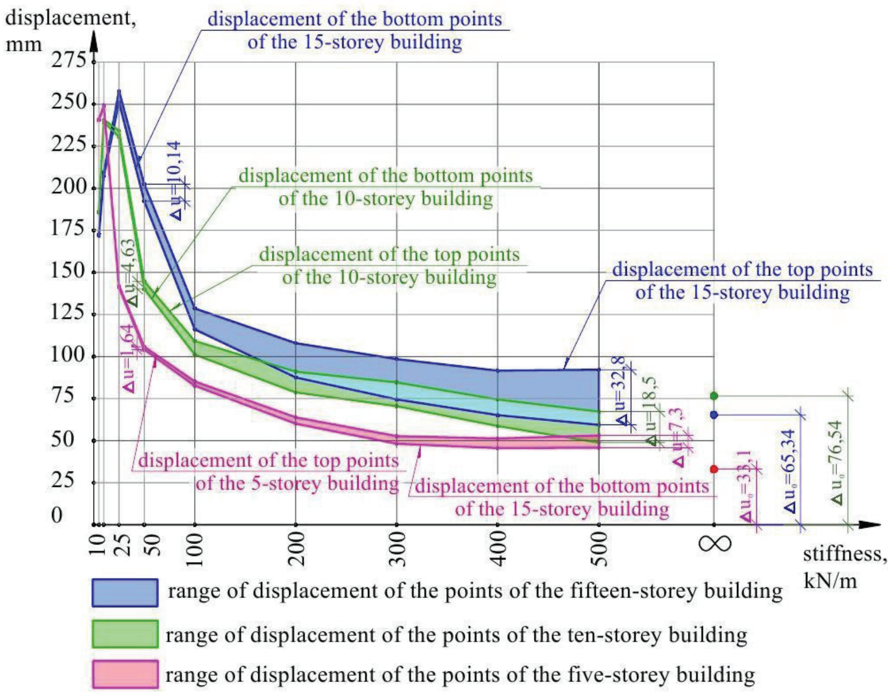

Fig. 6. Ranges of displacement of the points of a five-, ten- and fifteen-storey buildings

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Structural analysis was carried out by a dynamic method [2] by means of program SCAD. The calculation was made using three accelerograms for high hazard earthquake area (magnitude 8). In this investigation (Fig. 6) the range of the stiffness of damping bearings from K = 50 kN/m to K = 500 kN/m is of the greatest interest, because in this range there is the biggest decline of displacement (Δu) while decreasing the stiffness of the damper. Also, the system of the graphs (Fig. 6) demonstrates that the larger is the number of storeys in the building, the less rigid damping bearings should be designed to achieve high efficiency of their use.

CONCLUSIONS

The building of high-rise houses in high-risk earthquake zones is in a great demand in the modern world. So, damping bearings with low horizontal stiffness allow fulfilling this demand. Thus, application of non-traditional methods of seismic protection in high hazard earthquake areas is especially effective for building hospitals, which require long-term operations and storage centers for fragile items or antiques.

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