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THE VALUE OF THE VISCOUS FLUID DAMPERS FORCE RELATIVE TO BUILDING HEIGHT

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Abstract: *This paper presents the results of research carried out to determine the variation of viscous fluid dampers force as a function of building height. For this study, two damping percentages of relative level displacements, 40% and 50%, were considered. The study was carried out using a research-based software program made by Ionescu and Negru that involves a linear dynamic analysis based on a set of seismic accelerograms. Two buildings were considered, one with 11 floors and the other with 6 floors. The results of the study showed that the viscous fluid dampers force is reduced by approximately 72% for the 6-story building compared to the 11-story building, regardless of the damping percentage chosen for the analysis.*

Key words: *Damping force, viscous fluid damper, dynamic analysis, seism simulation, damping coefficient*

1. INTRODUCTION

Equipping buildings with anti-seismic protection systems is a common fact in countries with high seismicity. These systems can equip the structure in the foundation or on the supra-structure. The most widespread supra-structure systems for dissipating the seismic absorbed by the building are viscous fluid dampers that are characterized by a hysteresis loop that represents one of the most effective ways of dissipating seismic energy [1].

Viscous fluid dampers reach their maximum damping force when the deformation speed of the building during the earthquake is maximum, in other words, when the building relative level displacement is zero. This fact is an advantage from the point of view of the stress on the building frame nodes, which are thus loaded to the maximum value of the damper force when they reach the position with zero relative level displacement and when the stresses and deformations state in the frame node is minimal [2]. The viscous fluid damper force is depending on the value of damping coefficient *c*.

The other types of shock absorbers have a damping force proportional to the story displacement, which implies that the maximum damper force is achieved when the relative level displacement is maximum.

The value of the force in the shock absorber cannot exceed a critical value because it amplifies the state of tension and deformations in the frame nodes of the building. Studies have shown that a value of 1000 kN for the force in viscous fluid shock absorbers is a safe maximum value that does not dangerously affect the local stiffness of the frame nodes [3].

One of the current research topics is the optimization of the damping coefficient of viscous fluid dampers for buildings of different heights and implicitly the determination of the damping force necessary to choose an optimal anti-seismic protection system [4].

Currently, there are no design standards that specify the method of calculating the forces in the shock absorbers necessary for optimal damping of buildings. Therefore, additional studies are needed to correlate the following important factors in the optimization of a system of dispersion of the seismic energy absorbed by the building [6]:

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- the value of the damper force that does not amplify the state of tension and deformation of the nodes;
- number of dampers per floor;
- the shape of the hysteresis loop of the shock absorbers.

This paper presents a variation of the damping force related to building relative displacements reduction percentage chosen and the height of the anti-seismic equipped building.

2. COMPUTATIONAL STUDY

For the analysis of the structure, a validated research-based software developed by Ionescu and Negru [4,5] was used. The software program requests the level stiffnesses and the value of the damping coefficient c for each viscous fluid dampers. The program performs a linear dynamic analysis and provides the resulting displacements of each level of the building, as well as the damping forces from each damper.

The system of differential equations that is the basis of our program is presented in a form necessary for the computational solution by the Matlab / Simulink program [1]:

$$\begin{aligned} \dot{\psi}_i &= \psi_{n+i}; \\ \dot{\psi}_{n+i} &= \mu_{i+1,i} \cdot 2\beta_{i+1} \cdot \omega_{i+1} \cdot \dot{x}_{i+1} - \\ &-\left(\mu_{i+1,i} \cdot 2\beta_{i+1} \cdot \omega_{i+1} + 2\beta_i \cdot \omega_i\right) \cdot \dot{x}_i + \\ &+2\beta_i \cdot \omega_i \cdot \dot{x}_{i-1} + \mu_{i+1,i} \cdot \omega_{i+1}^2 \cdot x_{i+1} - \\ &-\left(\mu_{i+1,i} \cdot \omega_{i+1}^2 + \omega_i^2\right) \cdot x_i + \\ &+\omega_i^2 \cdot x_{i-1} - \frac{F_i}{m_i} + \frac{F_{i+1}}{m_i} - \ddot{u} \end{aligned} \quad (1)$$

Where:

$$\frac{m_{i+1}}{m_i} = \mu_{i+1,i}$$

m_i – building level i mass;

x_i – building level displacement;

u – ground displacement during seism;

ω_i – local pulsation of level i;

β_i - critical damping fraction

F_i – the horizontal projection of the damping force from the shock absorbers.

For the study, we considered two classic reinforced concrete structures of 11 and 6 levels with 4 openings in the Ox direction and 3 openings in the Oy direction. The distance between the axes on the Ox direction is 5 m and between the axes on the Oy direction is 6 m. We considered that the structures are equipped with viscous fluid dampers anti-seismic protection system. This system consists of 4 dampers on each floor, one on each facade. The value of the damping coefficient was determined through several numerical tests, using our program, in order to ensure a 40% and 50% reduction of the relative level displacements, but not to exceed 1000 kN for the maximum damping force. In order to calculate the influence of 1000 kN damper force on frame node stress-strain state, we performed a simulation in ANSYS which show that this value does not implies dangerous values of the stress (Fig. 1, Fig. 2).

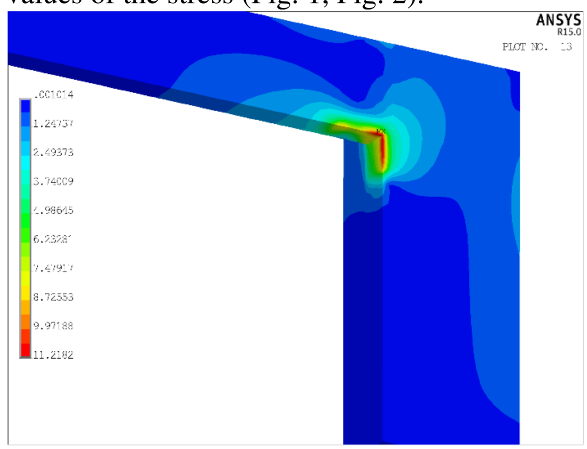

Fig. 1. Frame node concrete stress

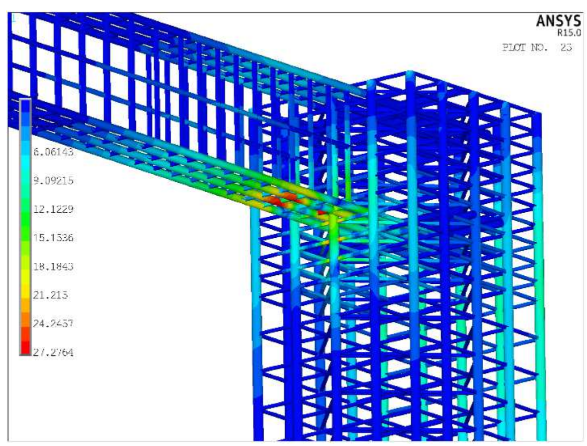

Fig. 2. Frame node reinforcement stress

The results obtained with our software are presented partialy in Fig. 3 – Fig. 20 for two levels of buildings relative displacements reduction (40% and 50%) using two seism accelerograms (Acc. 1 and Acc. 2) for control period Tc = 1.6 s, a_g = 0.3g, for both buildings, with 11 levels and 6 levels.

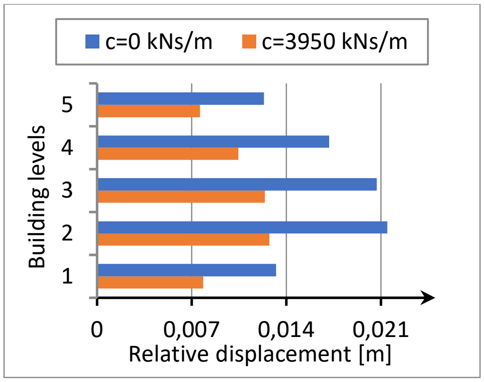

Fig. 3. Rel. displ., 6 levels, acc. 1 (50%)

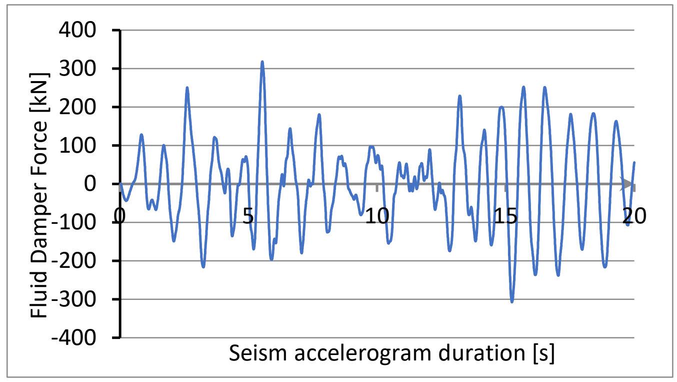

Fig. 4. Damper Force for 6 levels building, acc1

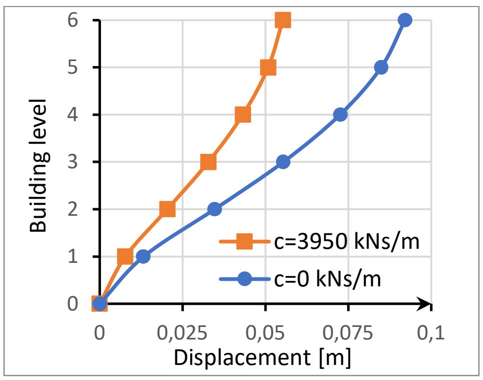

Fig. 5. Displacements, 6 levels, acc. 1, (50%)

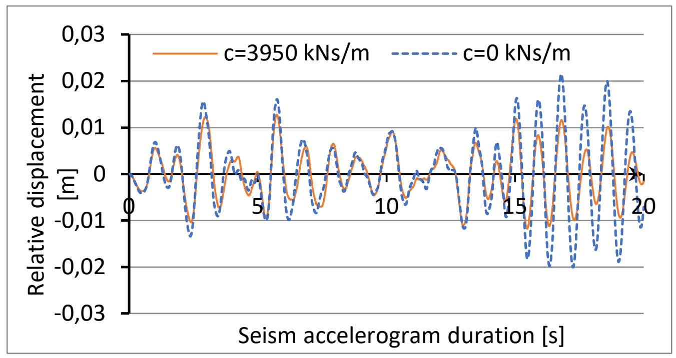

Fig. 6. Rel. displ., story 3, 6 levels, acc. 1

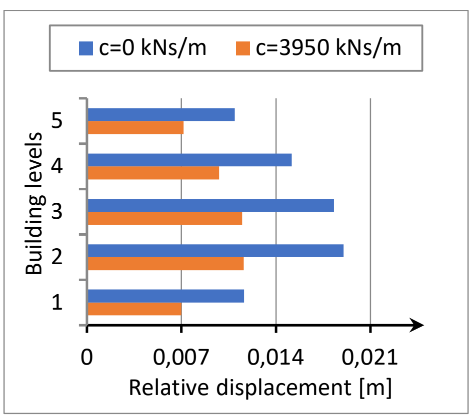

Fig. 7. Rel. displ., 6 levels, acc. 2, (50%)

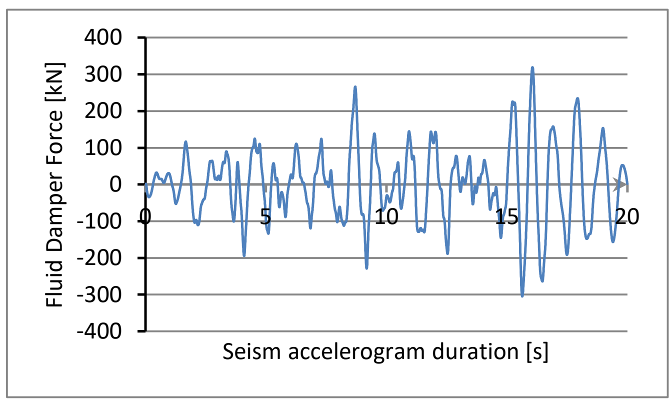

Fig. 8. Damper Force for 6 levels building, acc2

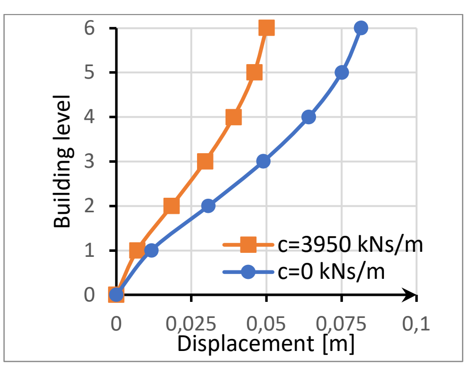

Fig. 9. Displacements, 6 levels, acc. 2, (50%)

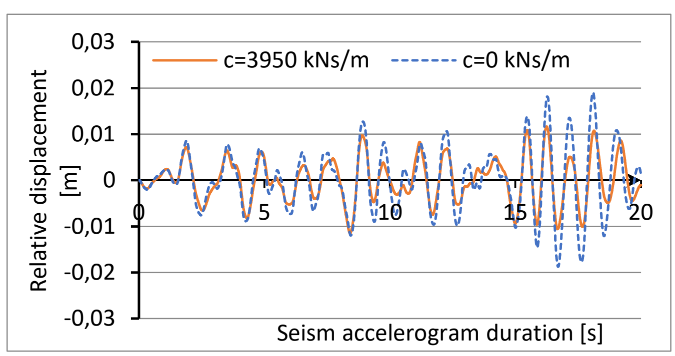

Fig. 10. Rel. displ., story 3, 6 levels, acc. 2

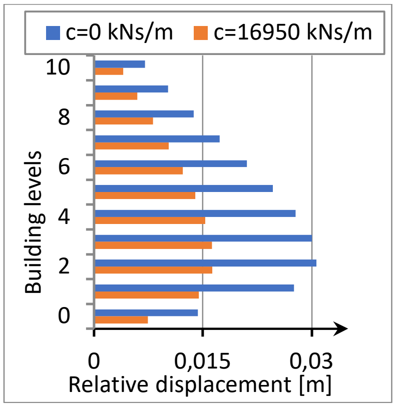

Fig. 11. Rel. displ., 11 levels, acc. 1 (50%)

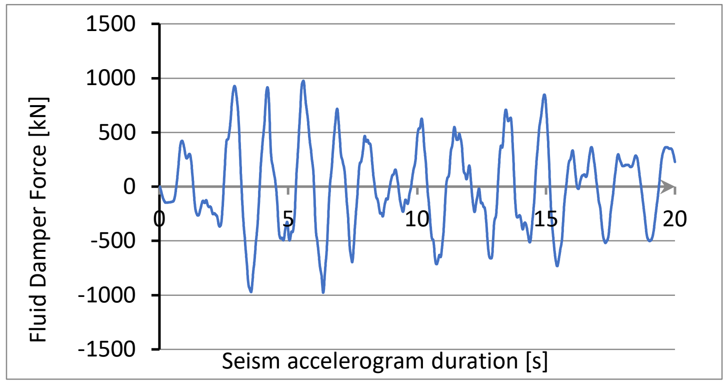

Fig. 12. Max. Damper Force for 11 levels, acc1

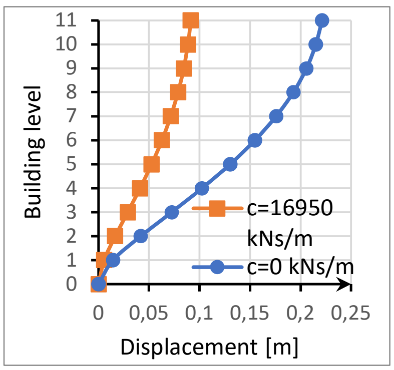

Fig. 13. Displ., 11 levels, acc. 1, (50%)

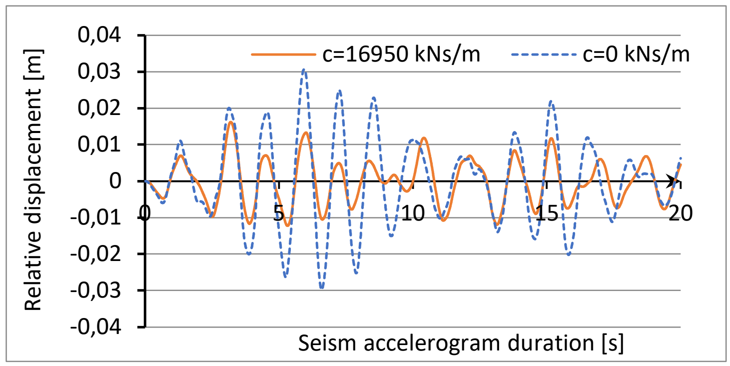

Fig. 14. Rel. displ., story 4, 11 levels, acc. 1

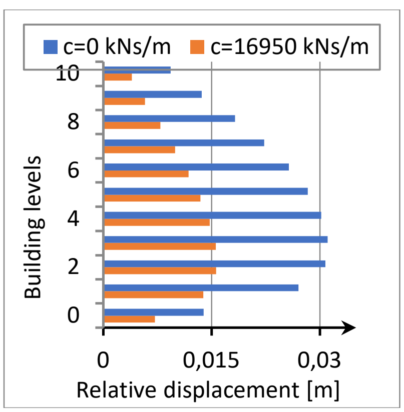

Fig. 15. Rel. displ., 11 levels, acc. 2 (50%)

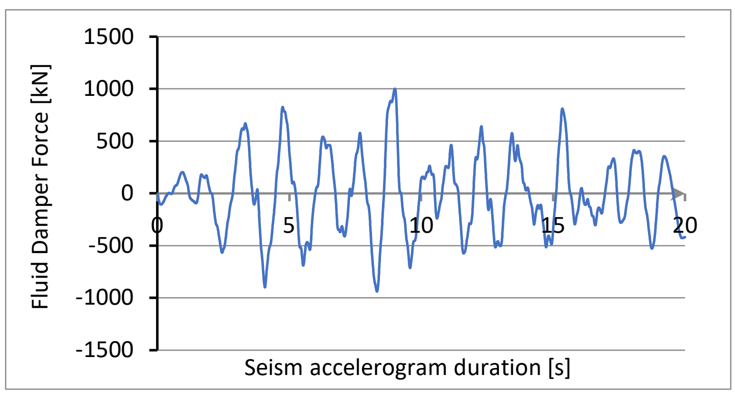

Fig. 16. Max. Damper Force for 11 levels, acc. 2 (50%)

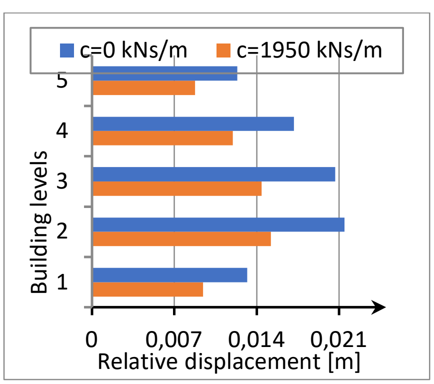

Fig. 17. Rel. displ. 6 levels, acc. 1, (40%)

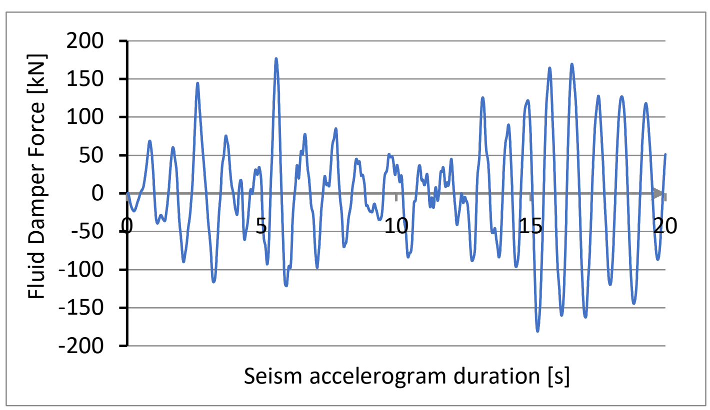

Fig. 18. Max. Damper Force for 6 levels, acc. 1 (40%)

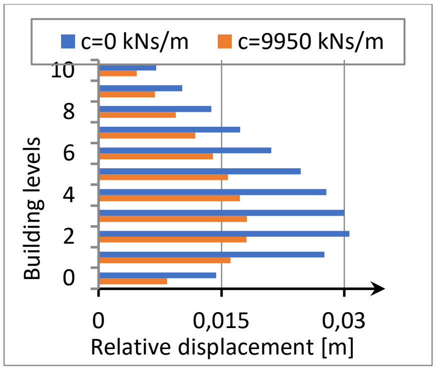

Fig. 19. Rel. displ., 11 levels, acc. 1 (40%)

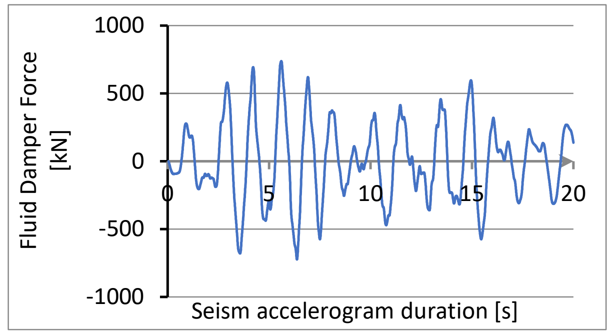

Fig. 20. Max. Damper Force for 11 levels, acc. 1 (40%)

Both seismic accelerograms acc.1 and acc.2 were computed with MSIMQKE software following the rules of seismic Romanian codes.

The damping coefficients of viscous fluid dampers that ensure reductions in the relative level displacements of the structure by 40% and 50% were determined with our software and are presented in Table 1.

Table 1

Average values of the damping coefficient *c* [kNs/m]

6 levels structure		11 levels structure	
Displacement damping		Displacement damping	
40%	50%	40%	50%
c = 1950	c = 3950	c = 9950	c = 16950

In Fig. 3. – Fig. 20. are presented for each of the two structures (6 levels, 11 levels), for both damping levels (40%, 50%) and for both seismic accelerograms used (Acc. 1, Acc. 2):

- the relative level displacements of the equipped structure (Fig. 3, 7, 11, 15, 19);
- the maximum damping force of viscous fluid dampers used for anti-seismic damping (Fig. 4, 8, 12, 16, 20)
- the relative displacements of the anti-seismic equipped structure (Fig. 5, 9, 13, 17);
- the maximum relative displacements during the earthquake (Fig. 6, 10, 14).

3. RESULTS AND DISCUSSIONS

The results of this study are presented in Table 2 for 50% displacements reduction and Table 3 for 40% displacements reduction.

Table 2 and Table 3 show that the fluid damper force reduction is 70-74% for 6 levels bui lding relative to 11 levels building for displacements damping of 40%-50%.

Table 2

Results obtained for 46-50% damping

Parameter	**11 levels**		**6 levels**		**Force red.**
	Acc.1	**Acc.2**	**Acc.1**	**Acc.2**	
Displ. reduction	49%	50%	47%	46%	-
Damper force [kN]	1000	1000	301	301	70%

Table 3

Results obtained for 35-41% damping

Parameter	**11 levels**		**6 levels**		**Force red.**
	Acc.1	**Acc.2**	**Acc.1**	**Acc.2**	
Displ. reduction	41%	40%	35%	39%	-
Damper force[kN]	740	750	190	194	74%

From Tables 2 and 3 it can be seen that:

- for the structure with 6 levels and the damping of relative level displacements by 40%, the force value in the viscous fluid damper is less than 20% of the maximum allowed value;
- for a 40% reduction in the displacements of the 11-level structure, the maximum dampers forces decrease by 25% compared to the case of 50% reduction in structure displacements;
- for a 40% displacements reduction of the 6-level structure, the maximum damper force decreases by 35% compared to the case of a 50% reduction in structure level displacements.

4. CONCLUSIONS

Using damper systems, the relative level displacements of the buildings are reduced by 40%-50%. The conclusions of this study show that for buildings with 11 levels, a 50% reduction in relative level displacements can be achieved with forces in viscous fluid dampers of maximum 1000 kN. For buildings of medium height, with 6 levels, the same damping of 50% is obtained with maximum forces in dampers 70% lower than in the case of tall buildings. The same in the case of a 40% reduction in the building's displacements.

Medium-height buildings require a maximum damper force below 20% of the maximum admissible damper force for tall buildings, which considerably reduces the costs of anti-seismic equipment.

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Valoarea forței de amortizare a amortizorilor cu fluid vâscos raportată la înălțimea clădirii

Rezumat: Această lucrare își propune să prezinte rezultatele cercetărilor efectuate pentru determinarea variației forței de amortizare din amortizorii cu fluid vâscos funcție de înălțimea clădirii. Pentru acest studiu s-au considerat două procente de amortizare a deplasărilor relative de nivel, de 40% și 50%. Studiul s-a realizat folosind un program software bazat pe cercetare realizat de Ionescu și Negru care implică o analiză dinamică liniară pe baza unui set de accelerograme seismice. S-au considerat două clădiri, una cu 11 nivele și cealaltă cu 6 nivele. Rezultatele studiului au arătat că forța de amortizare din amortizorii cu fluid vâscos se reduce cu aproximativ 72% pentru clădirea cu 6 nivele față de clădirea cu 11 nivele, indiferent de procentul de amortizare ales pentru analiză.

Cuvinte cheie: *forță de amortizare, amortizor de fluid vâscos, analiză dinamică, simulare seism, coeficient de amortizare*

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