Dynamic Seism Analysis of a Medium-Height Building Equipped with Two Variants of Anti-seismic Dampers

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Abstract. This paper presents a study of seism analysis of a reinforced concrete frame structure with a height of B + 5S, made in order to determine the performance of the damping system with viscous fluid that equips the superstructure for buildings of medium height (15–20 m). For this, the GenEcAm program developed by the authors was used, which performs a dynamic analysis using design accelerograms. Three cases of seismic analysis were considered: structure without anti-seismic equipment, structure equipped with viscous fluid dampers with damping coefficient $c = 2000$ kNs/m^2 and structure equipped with viscous fluid dampers with damping coefficient $c = 4000$ kNs/m^2. For these three cases of analysis, a set of nine design accelerograms made with the MSIMQKE program [1] was considered, three for each value of the corner period $T_c = 0.7$ s, $T_c = 1.0$ s and $T_c = 1.6$ s. We have performed 27 dynamic seismic analyzes of these three building cases with the GenEcAm program, for which the relative displacements of the level and the forces in the dampers were obtained as results. The processing of these results allowed us to conclude that for medium-height buildings the maximum relative level displacements decrease by 26%-29% when using viscous fluid dampers with $c = 2000$ kNs/m^2 and by 41%-48% when $c = 4000$ kNs/m^2.

Keywords: Dynamic Seismic Analysis · Fluid Viscous Damper · GenEcAm

1 Introduction

The variants of anti-seismic equipment of the structures involve the use of seismic isolators mounted in the foundation or seismic dampers mounted on the superstructure. Seismic dampers differ from each other by the shape of the hysteresis curve whose area is equivalent to the seismic energy dispersed by that damper.

Viscous fluid dampers have the largest area of the hysteresis loop. For their proper use, studies are needed to determine the necessary damping coefficient *c*. The damping force for a viscous fluid damper is:

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$$F = c \cdot v^{\alpha} \quad (1)$$

where: c – damping coefficient [kNs/m^2];

v – the velocity of the damper rod;

α – velocity exponent.

2 GenEcAm Dynamic Seismic Analysis

GenEcAm software (Fig. 1) made by the authors [2] is useful for dynamic seismic analysis of buildings equipped with different seismic protection systems that use for each damper or isolator one of the mathematical hysteresis models implemented in the program.

The analyzed structure has a ground floor and five stories and a height of 18 m. To analyze this structure the GenEcAm program requires the stories rigidities and masses and for the viscous fluid damping system requires the values of parameters c and α for each story.

For the study of the influence of the damping coefficient [4] on the decrease of the relative displacements, the following three cases were analyzed:

- Case 1 – Structure without seismic protection;
- Case 2 – Structure with viscous fluid dampers with $c = 2000$ kNs/m^2;
- Case 3 – Structure with viscous fluid dampers with $c = 4000$ kNs/m^2.

For each of the three cases, three design accelerograms created with the MSIMQKE program were considered [1] for each of the three corner periods $T_c = 0.7$ s, $T_c = 1.0$ s and $T_c = 1.6$ s. In Figs. 2, 3, 4, 5, 6, and 7 are presented the results offered by the GenEcAm program for the three analysis cases, for each story, in the form of the maximum relative displacements and the maximum force in the dampers. For their comparative study the results were presented on the same graph to observe the difference.

It is observed that the maximum relative level displacements in cases 2 and 3 are lower than those of the unprotected structure (case 1) by approximately 27.50% for $c = 2000$ kNs/m^2 and by approximately 45% for $c = 4000$ kNs/m^2.

It is observed that the maximum forces in the dampers have values of 300–320 kN for the case $c = 4000$ kNs/m^2 and are approximately 40% lower for the case $c = 2000$ kNs/m^2.

For $T_c = 1.6$ s the difference between the damping forces obtained for the two cases of seismic equipment is 44.50%, which is higher than the difference obtained for $T_c = 0.7$ s and $T_c = 1.0$ s.

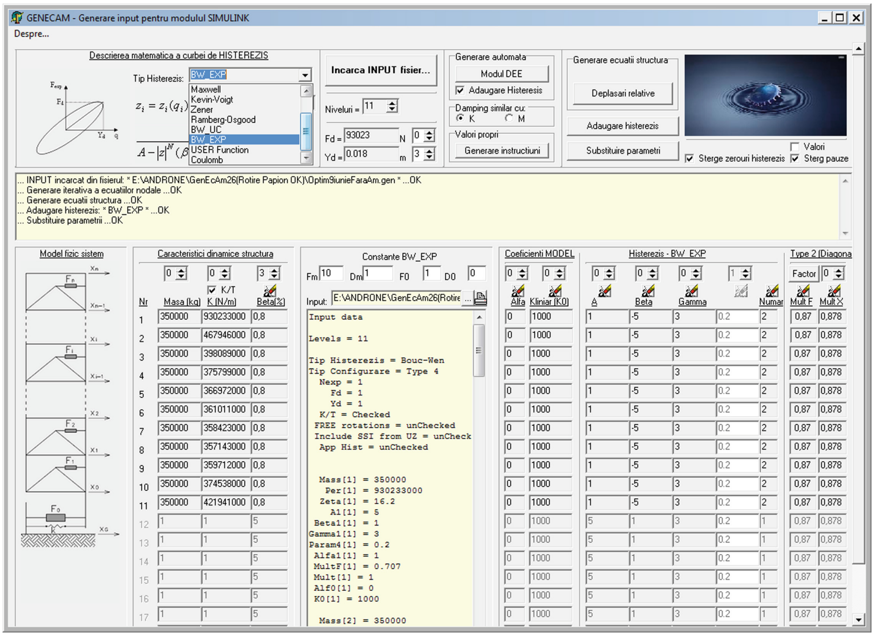

Fig. 1. GenEcAm program interface.

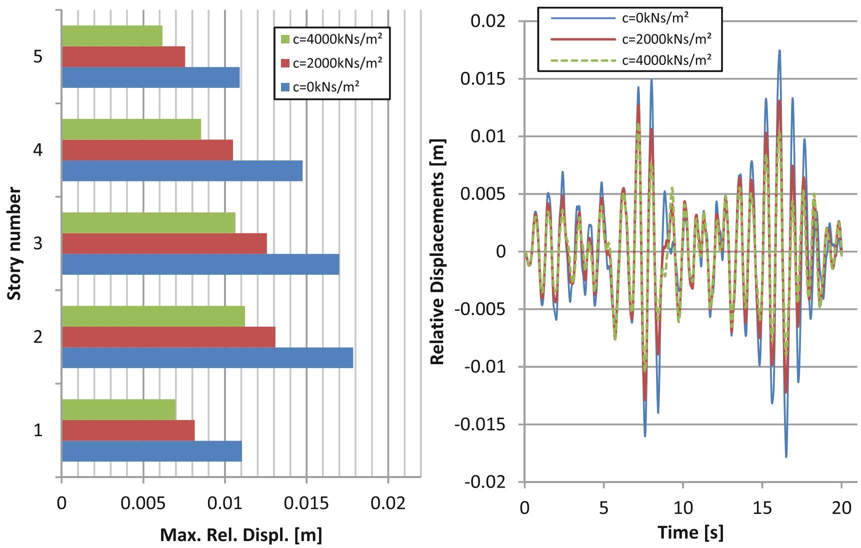

Fig. 2. Relative level displacements [m] for accelerogram 01 with $T_c = 0.7$ s.

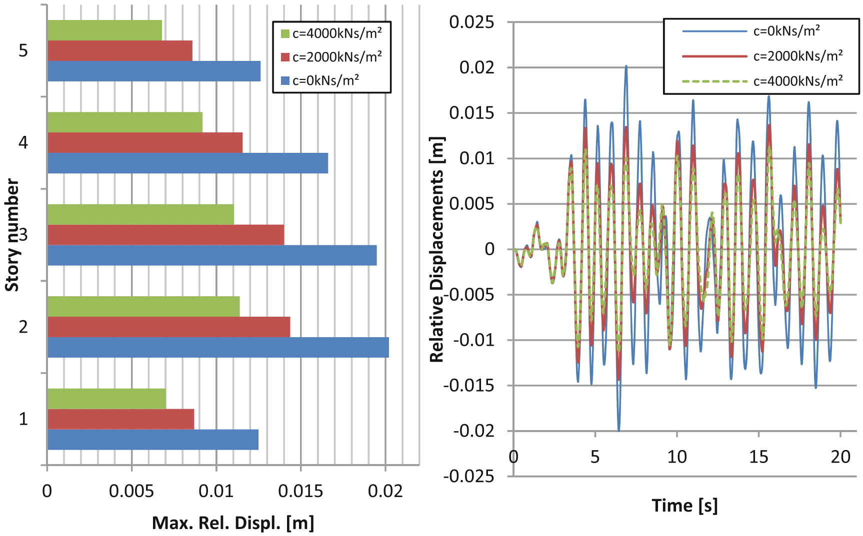

Fig. 3. Relative level displacements [m] for accelerogram 02 with $T_c = 1.0$ s.

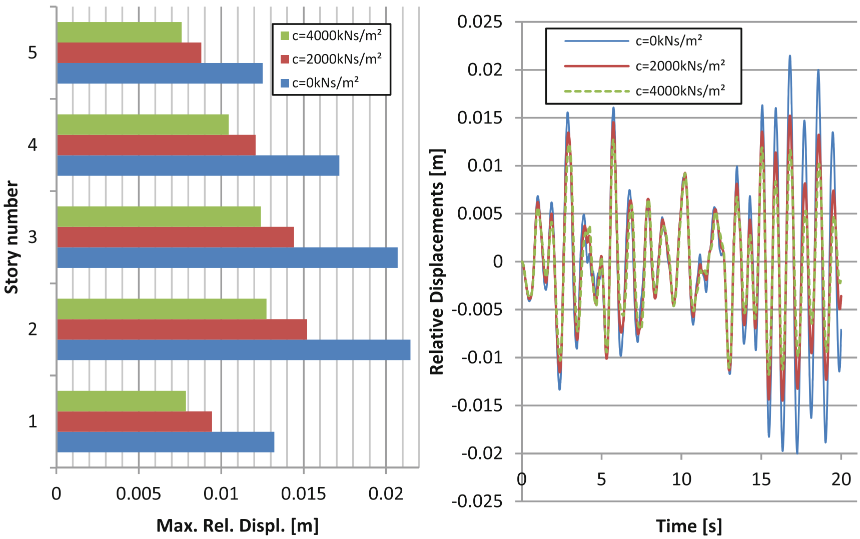

Fig. 4. Relative level displacements [m] for accelerogram 04 with $T_c = 1.6$ s.

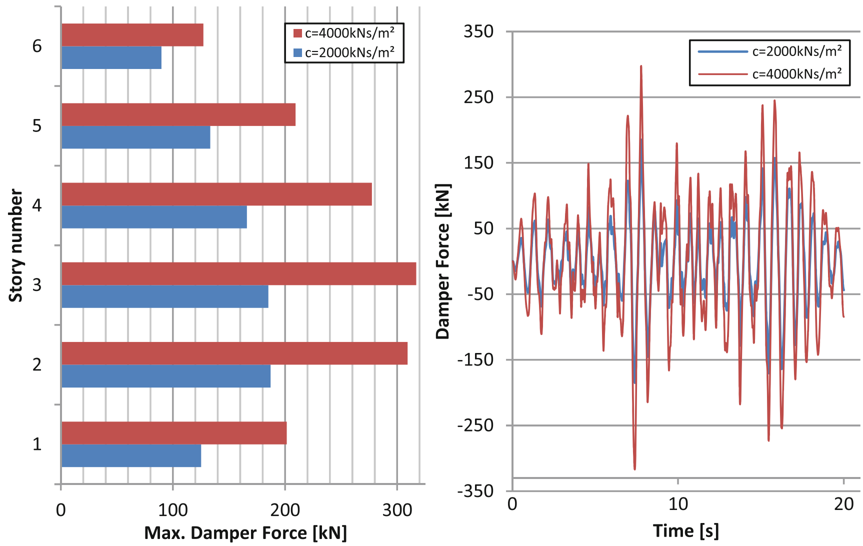

Fig. 5. Maximum damping forces [kN] for the accelerogram 01 with $T_c = 0.7$ s.

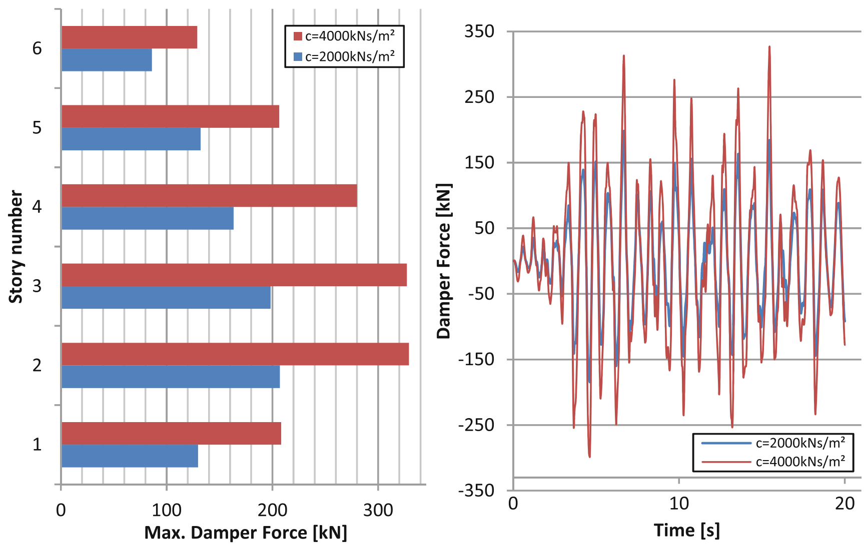

Fig. 6. Maximum damping forces [kN] for the accelerogram 02 with $T_c = 1.0$ s.

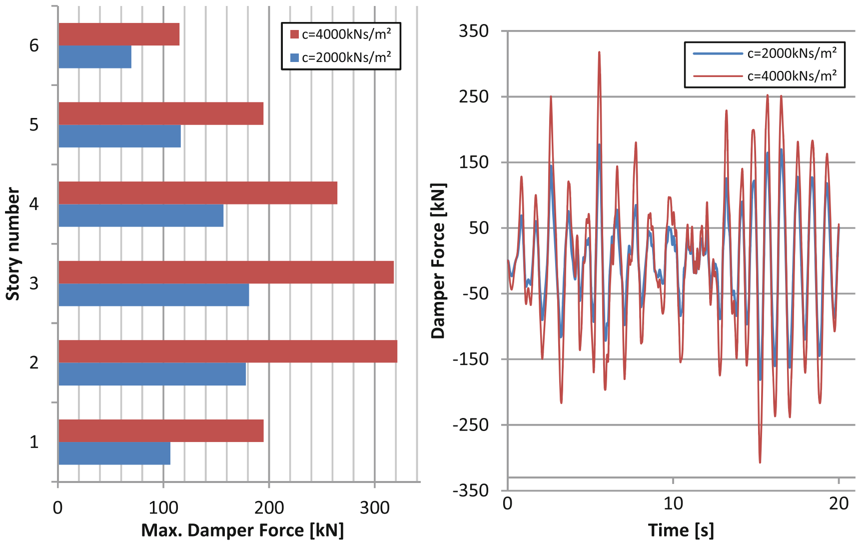

Fig. 7. Maximum damping forces [kN] for the accelerogram 04 with $T_c = 1.6$ s.

3 Conclusions

For the structure seism analysis, three dynamic analyzes were performed with different accelerograms for each value of the corner period: $T_c = 0.7$ s, $T_c = 1.0$ s and $T_c = 1.6$ s, in the three cases of seismic equipment of the building. Thus, 27 dynamic seism analyzes were performed with design accelerograms using the GenEcAm program.

The results obtained are the relative displacements of each story and the forces in the dampers. These results were processed to obtain a graphical difference between the relative maximum displacements and the maximum forces in the dampers, in order to highlight the influence of the damping coefficient on the performance of the seismic protection system with viscous fluid dampers.

Relative level displacements decrease by 26%–29% if the structure is protected with viscous fluid dampers with a damping coefficient $c = 2000$ kNs/m^2. If viscous fluid dampers with a damping coefficient $c = 4000$ kNs/m^2 are used, the displacements decrease by 41%–48%.

It must be considered that the use of dampers involves not only the dissipation of seismic energy through their hysteresis loop, but also the appearance of forces in the nodes of the structure in which the dampers were mounted. The higher the damping coefficient of the viscous fluid damper, the higher the forces acting on the nodes of the structure.

From the analysis of the obtained results it is observed that when doubling the value of the damping coefficient, the forces in the dampers increase by maximum 37%–44%. The determination of the damping coefficient of the dampers with viscous fluid is made taking into account the maximum forces in the dampers that during the seism will be induced in the nodes of the structure [3].

References

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