Mihai NEGRU, Adriana IONESCU

SOFTWARE FOR GRAPHIC POSTPROCESSING IN SEISM NUMERICAL SIMULATION OF THE BUILDINGS EQUIPPED WITH ANTISEISMIC DEVICES

Abstract: *This paper presents a graphic software made by the authors in Delphi programming in order to optimize the antiseismic device system of a building. The input data consists in the relative displacements for each story during the seism simulated with a certain accelerogram. The program can graphically process up to three data blocks obtained with GenEcAm software for the same building equipped with three different antiseismic systems. The advantage of this software is the graphical comparison of the story relative displacements during seism using different antiseismic system, in order to choose the best dissipative system for the building.*

Key words: *seism simulation, graphical post-processing, graphical comparison, animation, level displacement.*

1. INTRODUCTION

Earthquakes are one of the main natural phenomena that cause catastrophes with disastrous effects both on people's lives and on the built environment and the economy of the affected countries. Since the beginning of the 21st century, earthquakes caused the deaths of more than 900,000 people worldwide, the destruction of more than 500,000 buildings, the number of injured persons and damaged buildings being much higher.

Romania is characterized by intense seismicity in the epicentral area of Vrancea, with other epicentres with moderate seismicity. Consequently, the design of structures resistant to seismic movements is a major objective in structural engineering, both in the world, in high seismic countries, as well as in our country.

The antiseismic equipments of the structures involve the use of seismic isolators or seismic dampers, which are being applied on a wider scale in Japan, China, Russia, Italy, USA, as well as in other countries. The applications of these antiseismic equipments to buildings are already of increasing interest also in the research teams in Romania, the main inconvenience being the high cost of these devices, as well as the lack of regulations specific to the design of antiseismically equipped buildings.

The choice of seismic energy dissipation devices for a particular building is an important factor in the rational design of buildings in seismic areas. Therefore, a process of optimizing the choice of a building's dissipative system implies comparing the results of the earthquake analysis of the building with several anti-seismic equipment variants. The comparison results are: relative displacements, level relative displacements and forces in the dampers. These results highlight the efficiency of earthquake protection of a particular anti-seismic system for the analyzed building.

Since seismic behavior simulation programs do not allow real-time comparison of these results [1], we have written in the Delphi programming language, ProAnim, a program that compares the efficiency of three antiseismic dissipative systems of a building in order to choose optimal earthquake protection for the building under consideration.

The seism analysis result were obtained using GenEcAm, another software, made by the authors which assemble and solve the differential system of equations:

$$[M]\cdot\{\ddot{X}\}+[C]\cdot\{\dot{X}\}+[K]\cdot\{X\}+\{F_H\}=\\ =-[M]\cdot\{1\}\cdot\ddot{u} \tag{1}$$

where: $\ddot{u}$ - soil acceleration; {X} - displacements matrix; $\{1\}$ - unity vector; [K] – stiffness matrix; [*M*] - mass matrix; [C] – damping matrix.

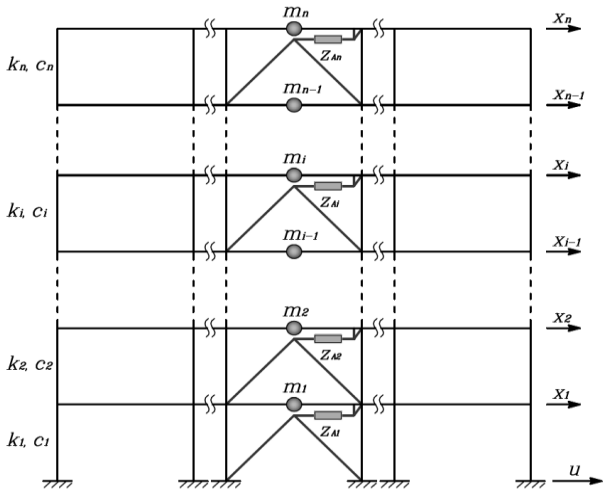

Fig. 1 Model of antiseismic equipped building

GenEcAm program [2] offer the possibility to choose between different types of seismic dampers [3] and isolator with different dissipative parameters, and solve de system (1) in order to obtain the displacements, speeds, accelerations and forces in seismic dampers.
These results are processed by ProAnim program which presents these results in a graphic manner.

2. PROANIM SOFTWARE PROGRAM

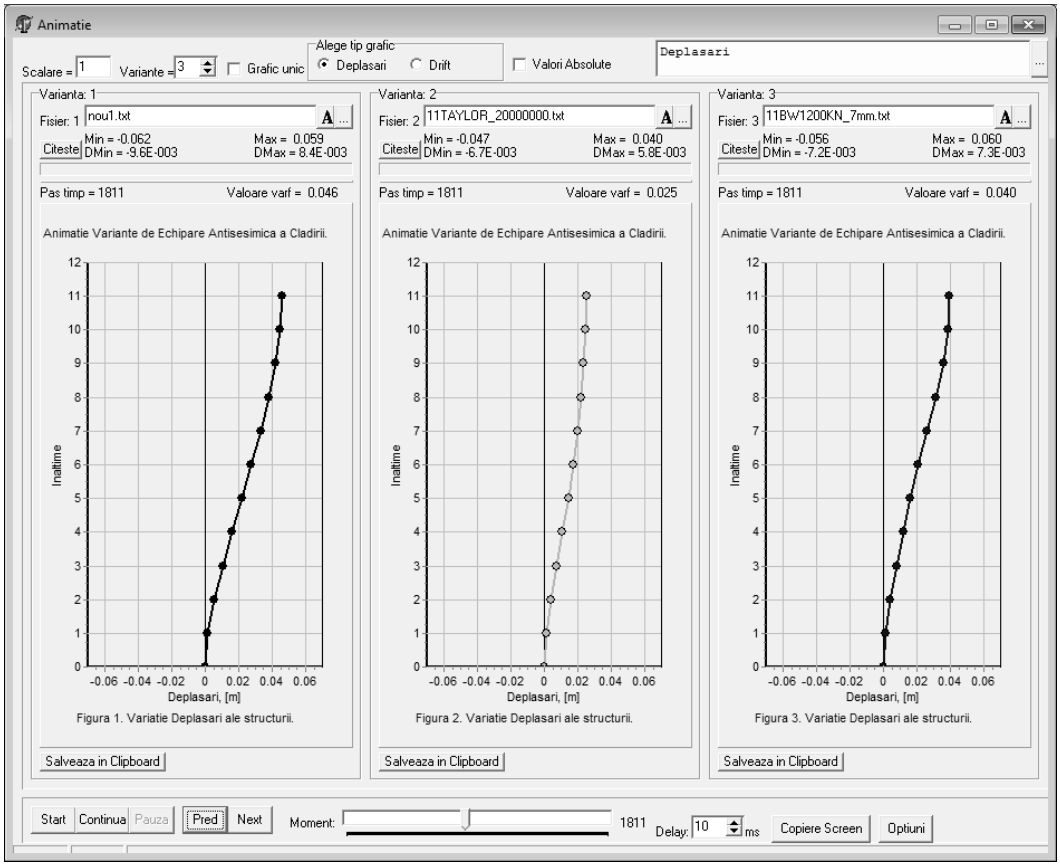

Fig. 2 ProAnim – graphical animation comparison of the building during seism

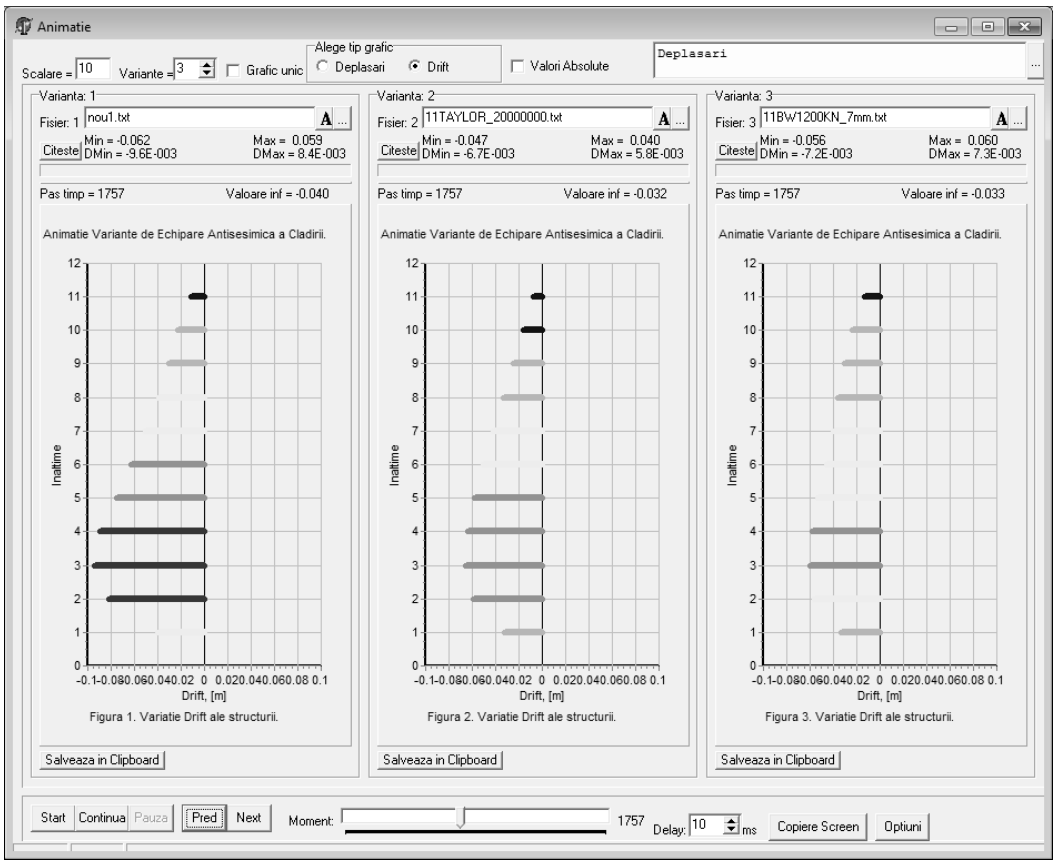

Fig. 3 ProAnim – graphical animation comparison of the relative level displacements during seism

The program allows simultaneous, comparative visualization of the results animation in three variants of antiseismic equipment of the same building, for the graphical evaluation of the performance of each damping system variant used.

The animation can be stopped at any time for detailed view of the relative displacements and relative level displacements for the three selected seismic equipment in order to be compared in detail. In Fig. 2 is the case of a B + 10L building with three antiseismic equipment:

a - no damping system;

b - with viscous fluid damper system;

c - with SERB damping system.

The "Grafic unic" option - allows the overlay animation of the three versions of the building to clearly distinguish the differences between relative displacements. In Fig. 4 are presented the results obtained on the analyzed building in all three antiseismic equipments variants.

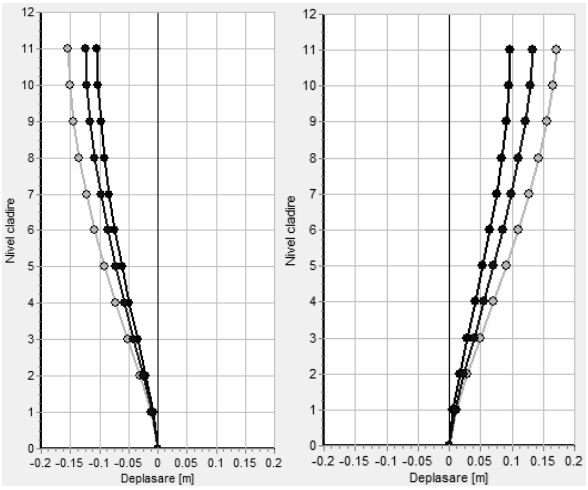

Fig. 4 Graphic comparison of the building relative displacements for the 3 cases (a, b, c)

"Drift" option - allows animation of relative level displacements of the building during seism using the three variants of antiseismic systems (Fig. 3, Fig. 5).

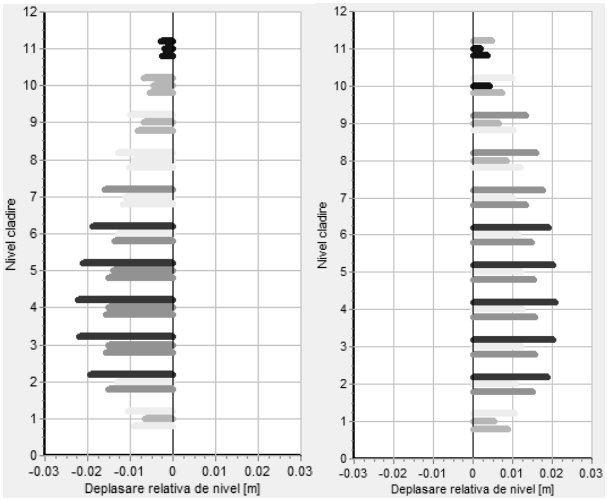

Fig. 5 Graphic comparison of building relative level displacements for the 3 cases (a, b, c)

In order to compare the damping forces values, ProAnim can present the variation of these forces in graphic animation, or on the same graphic at selected time during seism.

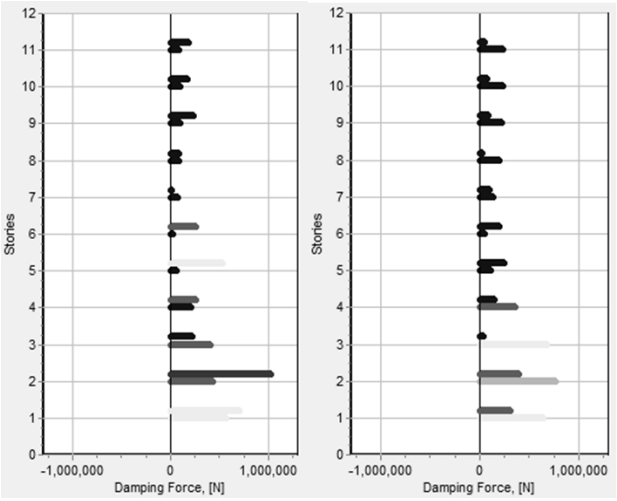

Fig. 6 Graphic comparison of the forces in level dampers for dissipative systems b and c

3. RESULTS

One of the studies made by the authors, using ProAnim software program, was to evaluate the efficiency of Romanian SERB dampers in dissipating the seism energy absorbed by the structural elements of the building.

The analysis of the building behavior during seism was made with GenEcAm software and the evaluation of SERB dampers was made by comparing the results with those obtained using Taylor dampers (VF). For a building with 10 stories, the comparison results are presented in Fig. 7. We have performed multiple analysis with different Taylor damping parameters and different number of SERB dampers on each story. The results presented in Fig. 7 and Fig. 8 were obtained using 4 Taylor dampers on each story and in the second analysis we have considered 8 SERB dampers on each story.

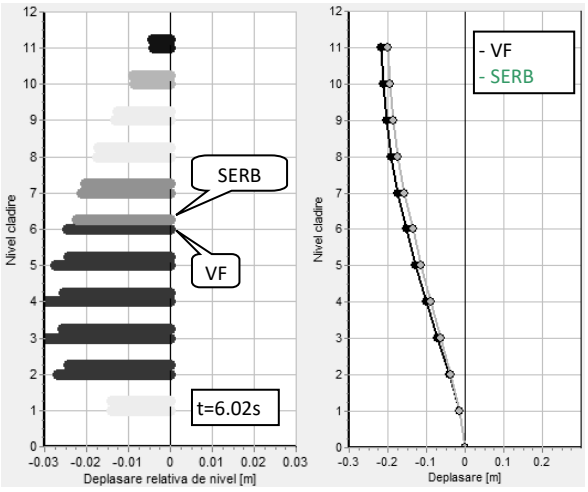

Fig. 7 Graphic comparison of the building displacements using Taylor dampers (VF) and SERB dampers (SERB), t=6.02s

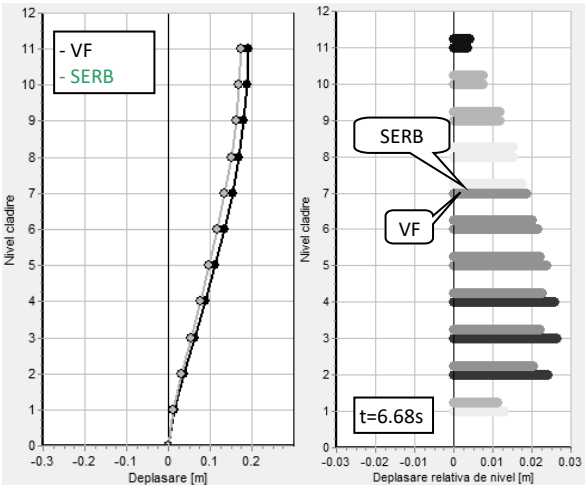

Fig. 8 Graphic comparison of the building displacements using Taylor dampers (VF) and SERB dampers (SERB), t=6.68s

ProAnim program presents the results as animation for the entire duration of seism, but it can be stopped at selected time, in order to observe the displacements differences. Fig. 7 and Fig. 8 are selected because at t=6.02 s and t=6.68 s the displacements were maximal.

We can observe that the displacements in both damper systems used are similar, and we can conclude that Romanian dampers are a valid option to be used as a valid damping system for the buildings.

4. CONCLUSIONS

ProAnim program, presented in this paper, aims at post-processing the results of the GenEcAm program, enabling:

- Graphical and animated view of building displacements during earthquake, simultaneously for up to three sets of GenEcAm [4] results. Relative displacements, but also relative level displacements can be viewed;
- Graphical and animated visualization of damping forces in dampers during earthquake, simultaneously for up to three results provided by GenEcAm.

The simultaneous presentation of GenEcAm's three sets of results, allows visual and value comparisons of these displacements and damping forces, thus offering the option of choosing the optimal damping system for the analyzed building.

ProAnim program is included in a set of 4 programs [5] made by the authors and they are a tool for designing the antiseismic equipment of a building, efficient and easy to use.

The results obtained in SERB dampers efficiency study [6], shows that using a double number of dampers it can be obtained a damping feature very similar with classical viscous fluid dampers.

Due to the low price of Romanian dampers, using SERB dampers instead of using Taylor dampers we can obtain the same amount of energy dissipation at a lower price (approximately half of price) [7].

REFERENCES

[1] Duta, A., Sass, L., Marinescu, G. C., Jeli, Z. (2017). *Modelling and simulation matters upon the static analysis of a building*, Journal of Industrial Design and Engineering Graphics, Special Issue no. 12, ISSN 2344-4681, pp 101-104.

[2] Adriana Ionescu, C. Burada, Mădălina Călbureanu, M. Negru (2014). *Computational model of buildings equipped with different devices for seismic damping*, WSEAS International Conference Brasov, Romania.

[3] Adriana Ionescu, C. Burada, M. Negru (2016). *Adapted Bouc-Wen Analytical Model for Romanian SERB-C Seismic Dampers Used in Buildings Protection System*, Applied Mechanics and Materials, Trans Tech Publications Inc., Swiss, ISSN 1662-7482. vol. 823/2016, pp. 91-94.

[4] A. Ionescu (2014). *Numerical model for earthquake analysis of buildings equipped with different devices for seismic damping*, CE-PhD 2014, 10-12 December, Cluj-Napoca, Romania.

[5] M. Negru, Adriana Ionescu, C. Burada (2016). *The Comparison Between Viscous Fluid Dampers and Romanian Friction Dampers Performance in Base Isolation System of Buildings*, Applied Mechanics and Materials, Trans Tech Publications Inc., ISSN 1662-7482, Swiss, vol. 822/2016, pp. 156-159.

[6] A. Ionescu (2014). *Using Bouc-Wen method for hysteresis curves simulation of BRB dampers and SERB new romanian dampers. Experimental and F.E.M. studies for SERB dampers*, CE-PhD 2014, 10-12 December, Cluj-Napoca, Romania.

[7] A. Ionescu (2014). *Computational studies for comparison between Taylor dampers and SERB dampers used in damping systems for a ten stories building*, Romanian Journal of Acoustic and Vibrations, nr. 2, ISSN: 1584-7284.

Authors:

Assoc. Prof. Mihai NEGRU, University of Craiova, Romania, Faculty of Mechanics,
E-mail: negrumih@yahoo.com
Assist. Prof. Adriana IONESCU, University of Craiova, Romania, Faculty of Mechanics, E-mail: adita_i@yahoo.com