RESEARCH REPORT NO.2

New anti-seismic protection systems for industrial buildings with seismic insulators and absorbers

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Content

Chapter 1 - THE STATE OF THE ISOLATION AND PROTECTION SYSTEMS AGAINST VIBRATIONS AND SEISMIC MOVEMENTS

1.1. Causes of vibrations in construction.

The vibrations of the constructions are due to internal or external sources. The internal sources represent: machines and equipment existing in the construction (machines - tools, compressors, engines of various types), rhythmic human activities, such as dance, sport, etc. The influence of the internal sources can be diminished by various means, such as: changing the operating regimes of the machines or machines, to avoid the possible resonances with the own frequencies of the buildings, placing these machines and machines on rigid elements, on vibrating insulators, etc. External sources: they are the most important effects that have a major influence on the constructions.

The main external sources are:

• noise from the environment;
• flow of fluids through pipes;
• road traffic and machinery, such as: compactors, excavators, etc .;
• the wind;
• earthquakes and explosions.

Earthquakes are the most significant dynamic tasks associated with construction. Their importance is due to both their size and their unpredictable manifestation.

1.2. The issue of protection against vibrations and seismic movements

In the specialty literature, the source protection of vibrations is also known as active protection, and that of the receiver, as passive protection. Active anti-seismic or vibration protection systems are complex systems that require the existence of automatic substances for the acquisition, processing, analysis and numerical control of the operation of the actual protection and / or isolation device against external disturbances. Passive anti-seismic or vibration protection systems - they are relatively simple systems, both from a constructive and a functional point of view. They do not use outside energy.

1.3. Seismic type vibration and wave protection is not a new field

As for the use of elastic elements for vibration insulation and protection, there is a wide range of materials used to insulate and protect constructions - such as metal, vulcanized rubber, cork, neoprene, etc. Research into the use of natural rubber-based elements has been developed since the 1970s. The first building with a U.S.-based insulation system was built in 1985.

This is a 4-storey building, with foundation and sub-foundation for the implementation of the base isolation system. The elastic insulation system consists of 98 multilayer insulators made of natural rubber reinforced with steel plates. The structure of the building is made of rigid metal frames, by means of connecting elements.

1.4 The principle of isolation of the base

1.4.1. General presentation of the principle of isolation of the base

In FIG. 1. is presented schematically the principle of isolation of the base of a structure against the effects of vibrations or seismic waves.

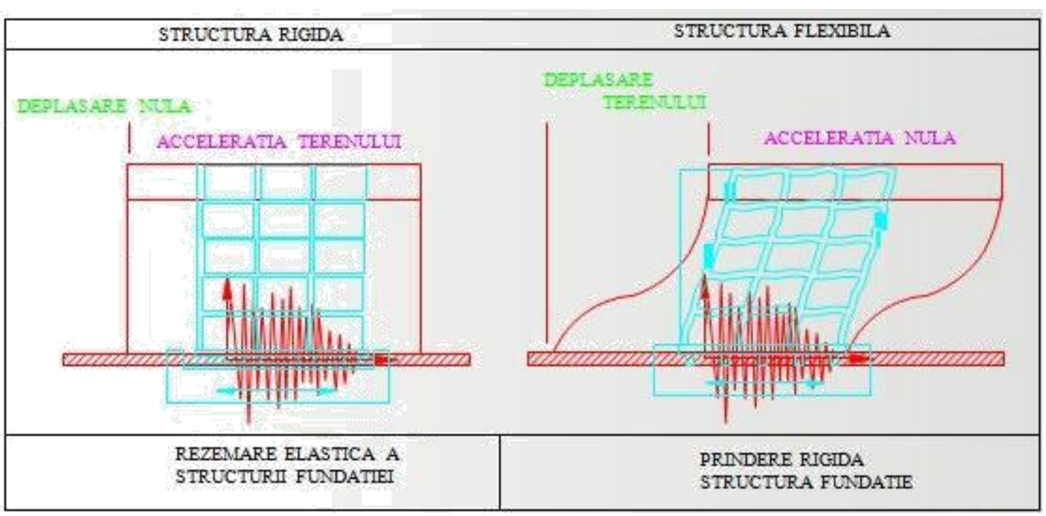


Figure 1. Principle of isolation of the base superposed with the behavior of the structures at the action of the vibrations and the seismic wave

1.4.2. Theory of base isolation

The simplest model of a system with static linear behavior is represented by an oscillator with only one degree of freedom, figure 2. The seismic (disturbing) action on the mass m is realized by moving the base of the oscillator with the ground during the earthquake. As a rule, the foundation is the foundation of a building to which its elastic resistance structure is linked. In FIG. 2. two reference systems were represented, namely: the inertial system O1x1y1 considered fixed and the Oxy mobile system connected with the basic solidarity (foundation).

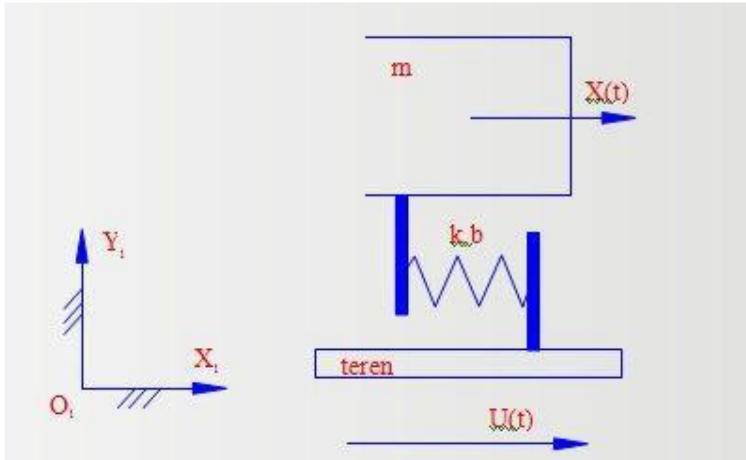


Figure 2. Model with a degree of freedom for studying the isolation of the base

At the time t = 0 the two reference systems coincide, the entire base - mass assembly of the oscillator is at rest (fig. 2). The action of the earthquake materialized by moving the base with u (t) in a translation movement, causes the mass m to have a relative displacement x (t), which causes the elastic forces kx and the viscous dissipatives to come into action.

The study of the movement of mass m can be done either in the relative coordinate x (t) or in the absolute coordinate x1 (t), taking into account that:

$$x1(t)=x(t)+u(t)$$

In relation to the absolute reference system the kinetic energy E, the potential energy of deformation V and the dissipative function D, can be expressed as:

$$E = \frac{1}{2}m(\dot{x} + \dot{u})^2 ; V = \frac{1}{2}k(x + u)^2 ; D = \frac{1}{2}b(\dot{x} + \dot{u})^2$$

In the past decades, the design of earthquake-resistant building structures has been based on the ductility of the structures, and after the major earthquakes (North, 1994; Kobe, 1995; Chi Chi, 1994; etc.). The ductile structures did not behave satisfactorily in such earthquakes. Therefore, the ductile design strategy consists in the fact that: 1. the mechanisms may not be realized in reality, with the presence of the existing walls; 2. the pillars may give in because of the rooms with large openings or under the effect of the short columns; 3. constructive difficulties, especially at the nodes (poles - beam), where the reinforcement is complicated after the ductile design of the structure.

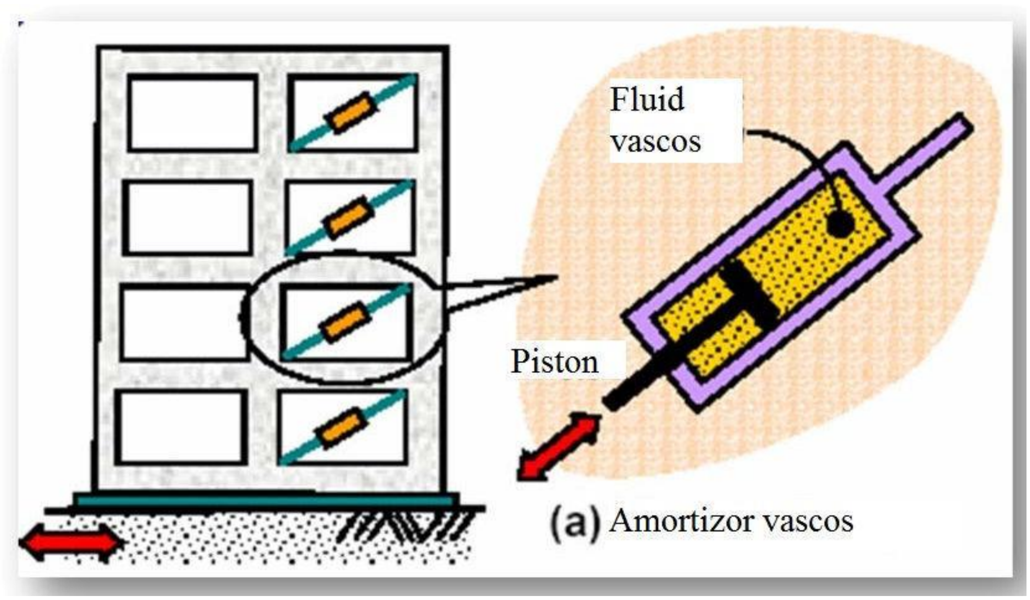
The seismic isolation of the base is more effective, being based on the fact that it maintains control over the structure of the building and has as its strategy the seismic isolation.

This includes the period of displacement of the structure and interruption of the load transmission column.

1.4.3 Vibration control

Dynamic absorbers and shock absorbers (Tuned Mass Dampers) realize a control system applied to the vibrations of the structure.

Disappearing types of energy produced by earthquakes and introduced into the construction structure can be viscous shock absorbers (a), frictional shock absorbers and deformation shock absorbers.



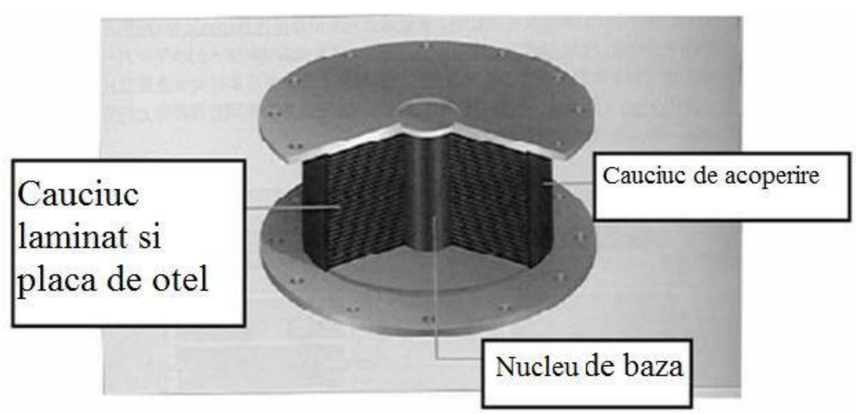


Fig. 3 Type of rubber insulation system.

The most important insulation systems of the base are a rubber base (L. R. B.; H. D. R. B.); and friction pendulum system (F.P.S)

Seismic isolation adequacy

The anti-seismic protection of structures, using the base isolation technology, is stable when the following conditions are met:

1. the foundation ground does not produce movements for a predominant period.
2. the structure should have columns with high resistance to stresses.
3. the position of the construction to allow lateral movement to 200 mm or more.
4. the lateral loads produced by the wind do not exceed 20% of the weight of the structure.**3.5**

Conclusions.

In this chapter we presented the causes of the vibrations introduced in the structure of resistance of the constructions, these are either from internal sources or from external sources.

In order to protect against vibration and seismic waves, current research in the field of insulation and protection against harmful effects is undertaken in several directions:

• protection at the source generating disturbance;
• protection on the propagation path of the disturbances;
• protection at the receiver (at the destination);
• combined protection.

This chapter presents the principle of basic insulation and some insulation systems at construction and other damping systems to take over horizontal loads caused by earthquakes or vibrations.

Chapter 2 - ANTI-ISISISMIC PROTECTION SOLUTIONS THROUGH SPECIAL SYSTEMS

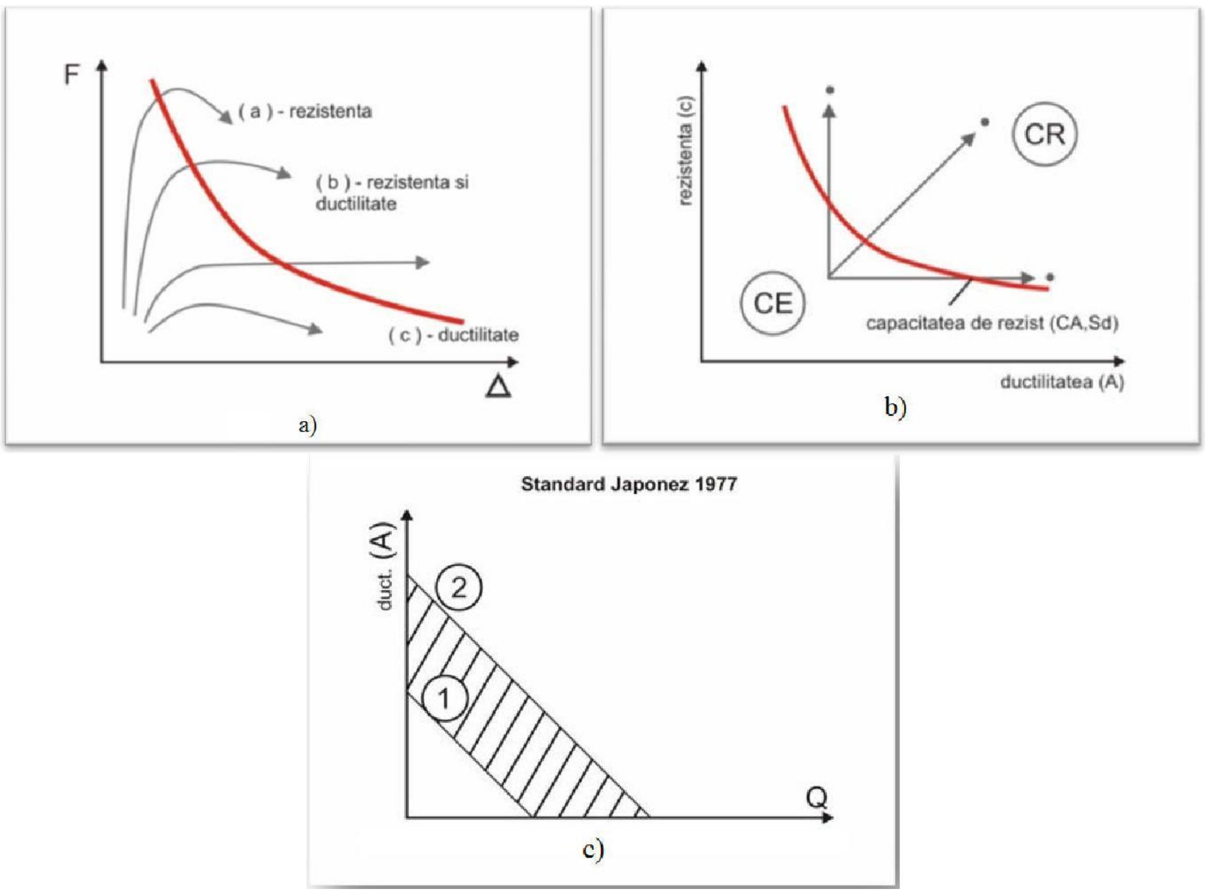
Special systems are systems whose presence influences the behavior of constructions to a greater or lesser extent - designed to play a favorable role - reducing the demands compared to the situation in which such systems are not provided. The systems comprise flexible components and dissipative components the flexible ones are linked in series and have the main role in modifying the overall rigidity of the construction and the dissipative components are linked in parallel - they have the main role, the introduction of areas capable of dissipating a large amount of energy through behavior, sometimes viscous, but usually hysterical elasto-plastic. Active systems are characterized by the fact that they introduce parameters that can be modified during the earthquake according to a command - which is normally automatic. Active systems can be oriented in the following main directions:

a) force generating systems capable of reducing the seismic demands of the construction;

b) custom-adjustable systems, during the earthquake - systems with variable inertial characteristics, systems with variable dissipative characteristics, systems with variable rigidity.

2.1 The conceptual basis of seismic "retrofitting"

Retrofit - the size of the resistance capacity, the ductility of energy dissipation. Basically, the "retrofitting concept" consists in bringing a building from the "CE" (existing building) to the "CR" safety zone (retrofitted building) (fig. 4), by adopting solutions to increase the stiffness of the curve. "A, curve" b ", by increasing the resistance and ductility and curve" c ", by increasing the ductility, respectively the dissipation capacity of the seismic energy.



2.2. Structural dissipator systems

The selection of the damping systems is made according to the characteristics of the structural type and the particularities of the seismic action, corresponding to a given location. They can be grouped into:

• directional heat sinks;

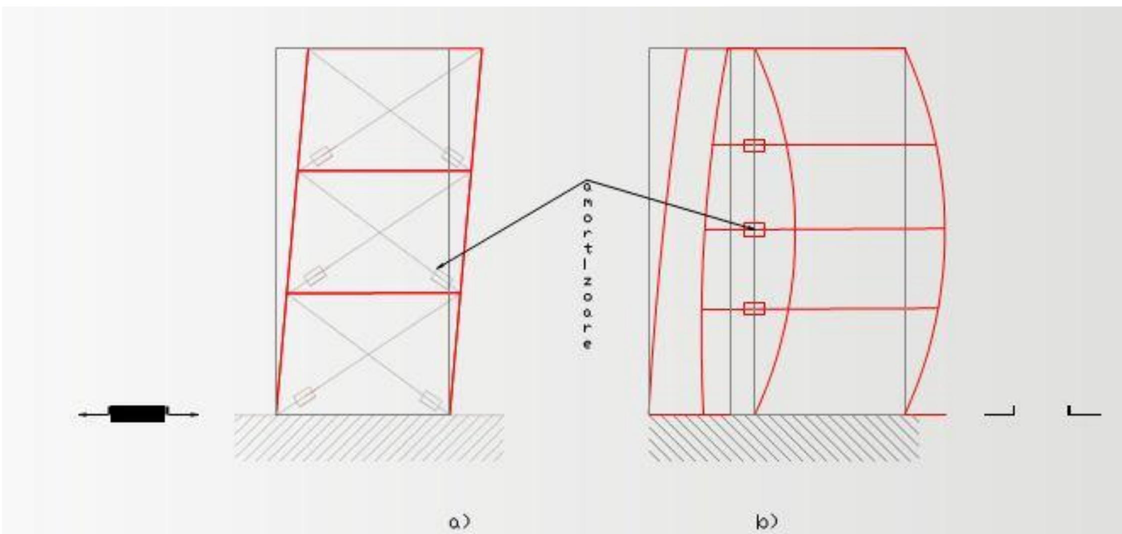
• inertial dissipators;

• heatsink wall;

• eccentric dissipative systems (links);

• dissipation systems from stiffening and dissipation plates.

Directional dissipators:



Structure with hysteretic dampers: - a) flexible frame; b) mixed frame-diaphragm structure;

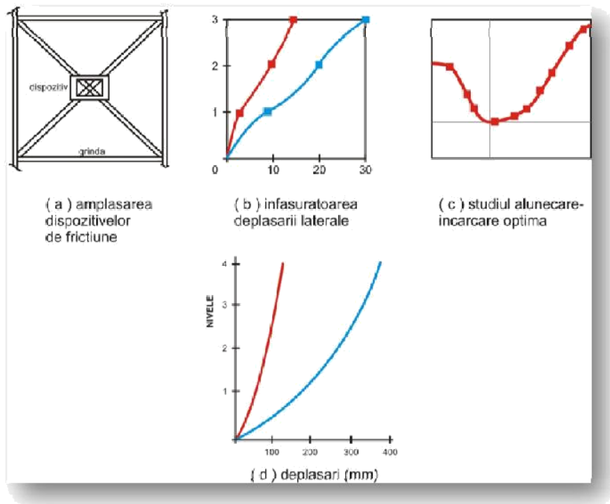
The arrangement of the directional dissipators in the structure is made as in the above figure or only in the areas with maximum relative deformability.

They can be:

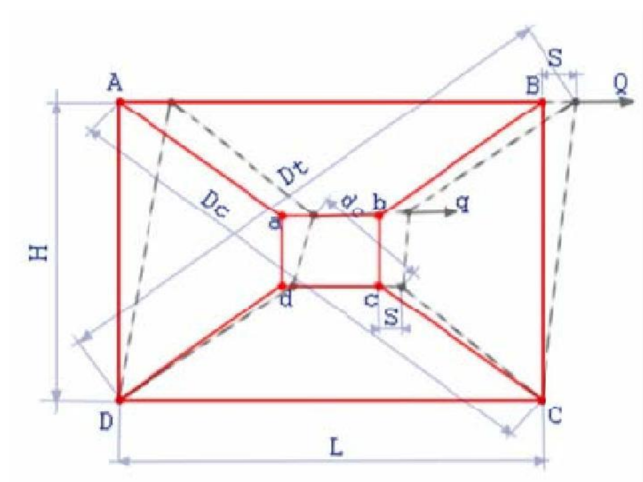
- hysteretic elastic type;
- visco-elastic;
- with friction;
- with energy absorption through deformability.

Studies on structural systems, equipped with linear hysteretic dampers, show that these systems can reduce efforts in the elements of a structure and frames by 36-48%.

Studies made for constructions equipped with frictional diagonal devices have shown reductions in displacements by 1/3, of efforts in pillars by 60%, and in beams by 50%, and in floor by 33%.

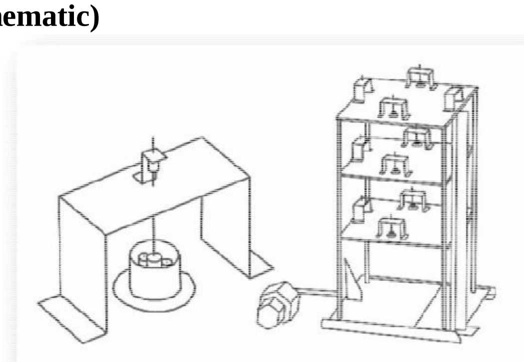


For constructions equipped with diagonal friction devices



Deformation of the rectangular device

Planar dissipators (kinematic)



Planar dissipators

They are tuned to the fundamental frequency of the structure. These can reduce the seismic action induced in the structure by 25-30%.

Dissipator wall

The wall can be in sliding form, placed in the areas of maximum, vertical landslides. They can reduce the relative displacements by 1.5-2 times, respectively reducing the efforts on average by 40-50%.

They have the disadvantage that they have a large mass, which entails concomitant with the increase of the able energy of the structure and an increase of the forces of inertia due to their additional mass introduced into the structure.

Dissipators made by eccentric contraventions (links)

The advantages of using such dissipators in metal frame structures as compared to the classical contraventions are:

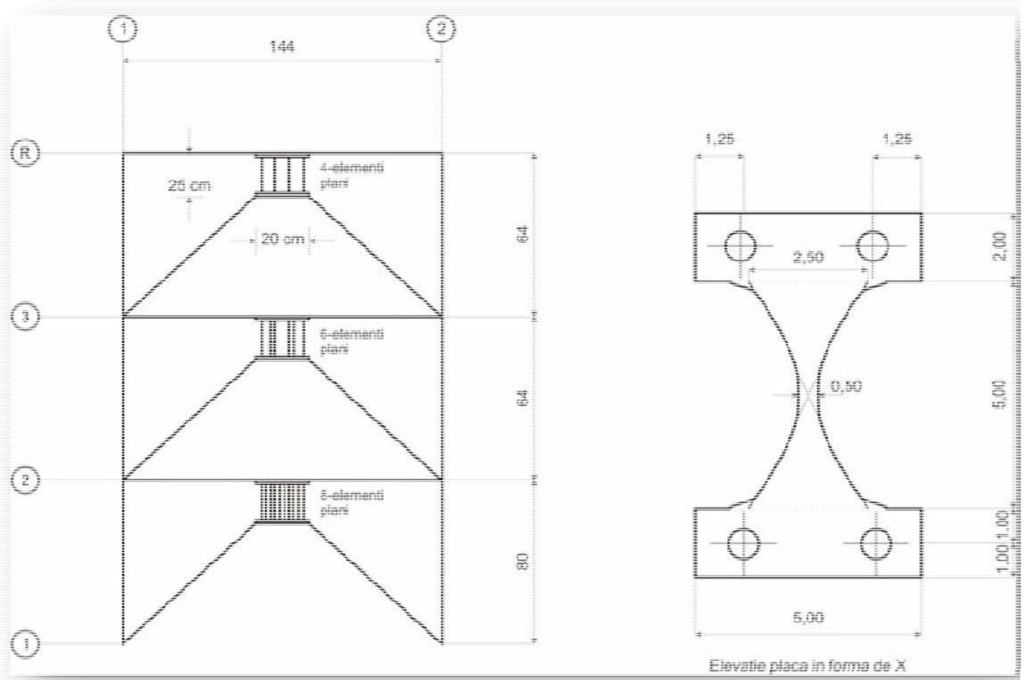
• approximately equal lateral rigidity;

• the dissipation capacity of the seismic energy, much higher, and well controlled;

• consumers with 25 - 30% lower;

• taking over the lateral loads with about 70% through these contraventions and 30% being through pillars.

Dissipators from stiffening and dissipation plates in the form of X and PL-X



Dissipators from stiffening and dissipation plates in the form of X and PL-X

2.3 Conclusions

Special anti-seismic protection systems fall into 2 categories: active systems and passive systems.

The concept of retrofitting consists in bringing a building from the area of insecurity to the area of safety by adapting solutions to increase the rigidity, the resistance, the ductility and the dissipation of the seismic energy. The reduction of the amount of energy induced in the structure is done by systems of damping or dissipating the seismic energy at the base of the construction.

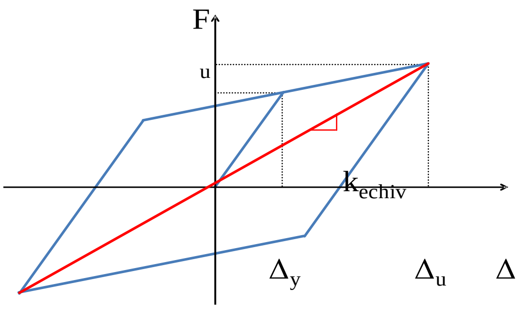
The dissipation and the restitution respectively are obtained at this level, the selection of the damping systems is made according to the characteristics of the structural type and the particularities of the seismic action.

The structural dissipative systems of some damping systems can be grouped into directional dissipators, inertial dissipators, dissipative wall, eccentric dissipative systems (links) and dissipation systems from the regularization and dissipation plates.

Chapter 3 - METHODS OF CALCULATION FOR STRUCTURES EQUIPPED WITH SEISMIC ISOLATORS

In the design codes, simplified methods of linear elastic type calculation are presented, which helps to pre-size the insulation systems. In addition to these methods, the codes recommend the use of non-linear dynamic computation methods, which aim to verify the solutions obtained by the simplified method.

3.1. Method of elastic linear calculation of insulation systems



This subchapter presents the linear elastic calculation method F according to the Romanian code P100-1: 2006 and the American Fy code ASCE 7-05

This method involves a simplified calculation of seismic isolators. Thus the insulation system is modeled using an equivalent linear behavior, having rigidity equal to the slope of the line in the force-displacement graph a of an insulator shown in figure 7.

Figure 7. Equivalence of the behavior of a seismic isolator with a linear system

The stages of dimensioning an insulation system for a building

1. Determine the axial forces at the base of each pole (N)
2. Depending on the axial force, the value of the diameter of an insulator can be determined

3.2. Case Study

The case study refers to the analysis of three models of structures, the main element that differentiates between them is the period of fundamental vibration.

Vibration periods were considered so as to cover a wide range of real structures affected by earthquakes in Vrancea source. Thus, the target vibration periods of the fixed-base structures are T_1 = 0.5 s; T_2 = 0.7 s şi T_3 = 1.0 s.

The following four cases were considered:

- Structure without insulation devices, with a fixed base.
- Structure with insulated base (vibration period of the isolation system of 2 seconds).
- Structure with insulated base (vibration period of the isolation system of 3 seconds).

Structure with insulated base (vibration period of the isolation system of 4.8 seconds).

For the modeling of the insulation system of the base, in the three variants, we considered the structure placed on a reinforced concrete slab having a thickness of 70 cm, thus resulting in a mass M "= 393.75 tonnes.

of 16 "link" elements, considering a depreciation coefficient ξ = 10% of the critical depreciation

The three chosen structures were analyzed, at the action of the seismic motion recorded at INCERC Bucharest, the Vrancea source, 04.03.1977 NS component, considering a linear elastic response

In order to compare the response of the analyzed structures to the seismic action considered, the horizontal relative displacement at the last level of the structures was followed. Another element of comparison is the basic cutting force. Figure 8 and 9 show the relative displacement respectively the level cutting force for structure 2

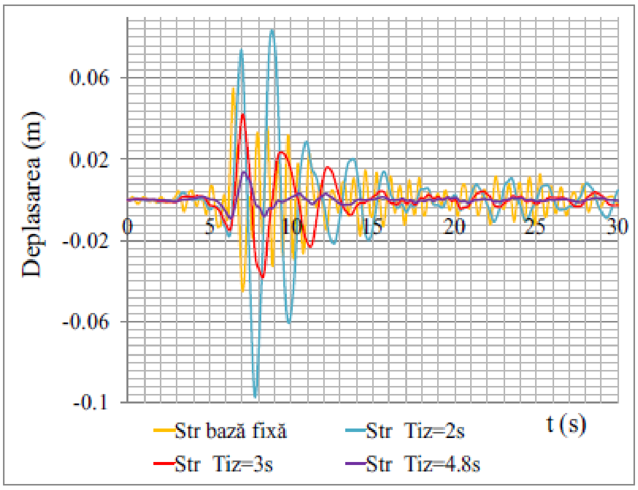


Figura 8. Deplasarea la vârf pentru structura 2

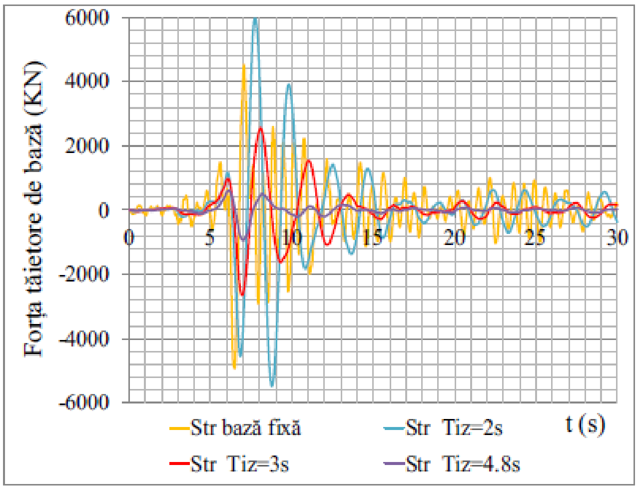


Figura 9. Forţa tăietoare de bază pentru structura 2

By using an isolation system with the isolation period of two seconds, it results for structure 1 and structure 2 displacements at the tip higher than in the case of the fixed base structure, and for structure 3 displacements approximately the same with the non-insulated structure. This can be explained by the fact that structures with base isolation systems that have a two-second isolation period are in a resonance zone with the predominant oscillations of the ground. The basic cutting force in the system isolated with T = 2s is higher in the case of structures 1 and 2 than in the case of the non-isolated structure. For structure 1 and 2 isolated with T = 2s, Fb = 3904KN and, respectively, Fb = 5960KN, front of structure1 and structure2 isolated, Fb = 2917KN and, respectively, Fb = 4527KN. For structure 3 insulated with T = 2s the cutting force (Fb = 8270KN) is smaller than for structure 3 not insulated, Fb = 13625KN.If the ratio of the forced to the base of the structure is not isolated,

The behavior factor q of the non-isolated structure with incursions in the inelastic field of behavior is equal to 5. The difference between the two values of the behavioral factors qechiv <q shows that the isolated structure has incursions in the plastic field of behavior. The ideal purpose of the insulation is for the structure to behave in the elastic domain. The isolation system with T = 2s in these structures produces an amplification of the displacements and the efforts corresponding to a resonance form

Structura	$F_b^{\text{bază fixa}}$	$F_b^{\text{izolată T=3s}}$	q_{echiv}
STR1	2917	1630	1,79
STR2	4527	2560	1,77
STR3	13625	3724	3,66

Structura	$F_b^{\text{bază fixa}}$	$F_b^{\text{izolată T=4,8s}}$	q_{echiv}
STR1	2917	380	7,67
STR2	4527	602	7,52
STR3	13625	950	14,3

Structura	$F_b^{\text{bază fixa}}$	$F_b^{\text{izolată T=3s}}$	q_{echiv}
STR1	2917	1630	1,79
STR2	4527	2560	1,77
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STR1	2917	380	7,67
STR2	4527	602	7,52
STR3	13625	950	14,3

For the system of isolation of the base with T = 3s it is observed that the peak displacements are smaller than in the case of non-insulated structures. The calculated values of the behavior factor are smaller than the value of the behavior factor of the non-isolated structure designed for q = 5. And in this case the three isolated structures will have incursions in the plastic field. The base isolation system with T = 3 s is more efficient than the base isolation system with T = 2 s but the behavior of the structures is not elastic.

An important response in terms of reducing the effects of the seismic motion can be observed in the case of the base isolation system, for which the period of vibration of the isolation system is 4.8 seconds. The reduction of the displacements at the top of the analyzed structures is between 20% and 30%. The calculated values of the behavioral factors are greater than the value of the behavioral factor (q = 5) used in designing the structure with a fixed basis in all three cases analyzed. The three structures will have a behavior in the elastic domain for the insulation system with T = 4.8 s. It can be observed that for the structure 3 the differences between the behavioral factors is large qechiv> q and as a consequence structure 3 another isolation system with an isolation period between 3 s and 4.8 s can be used.

In conclusion, to use the isolation systems of the support base, the characteristics of the insulators should be chosen according to the performance objectives pursued for the analyzed building.

3.3. Nonlinear dynamic calculation method of insulation systems

In the non-linear dynamic calculation method, the seismic action is modeled with the help of accelerograms recorded under different location conditions and with the help of artificial accelerograms, which are generated so that they are compatible with the design spectrum.

3.4. Optimization of seismic isolation systems

3.4.1. Introduction

Using the elastic-linear calculation method, a relatively easy insulation system can be dimensioned. Difficulty occurs when the chosen solution is verified by a non-linear dynamic calculation. As a result of the dynamic analysis, another more efficient isolation solution can be reached. This solution may or may not be the optimal solution.

The following will present an optimization method for seismic isolation sizing using genetic algorithms.

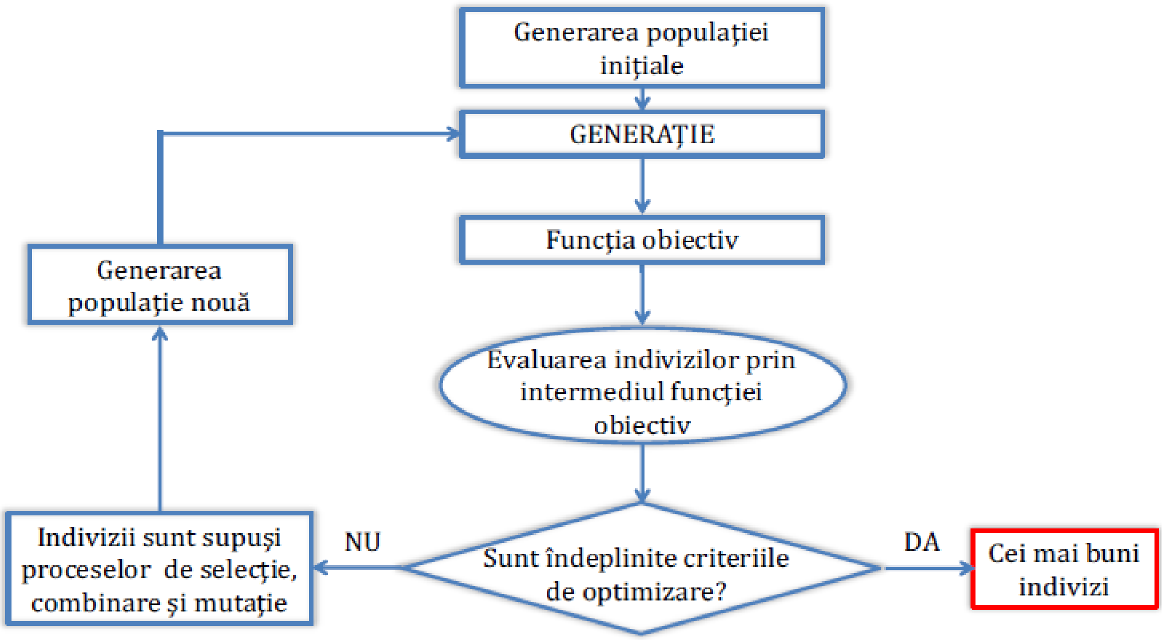

Figura 10. Structura unui algoritm genetic

The philosophy of the genetic algorithm consists of: Generation of the initial population is performed randomly. The initial population must contain a large variety of individuals. An objective function is determined, which measures how well the individual is adapted to the environment. The objective function must be positive and the greater the better the individual. In the evaluation phase of individuals, the objective function for each candidate will be calculated. The selection phase of new populations is made in relation to the objective function and can be of several types, of which we mention the roulette type selection and the tournament type selection.

3.4.2. Determination of the dimensions of a circular rubber insulator with a lead core

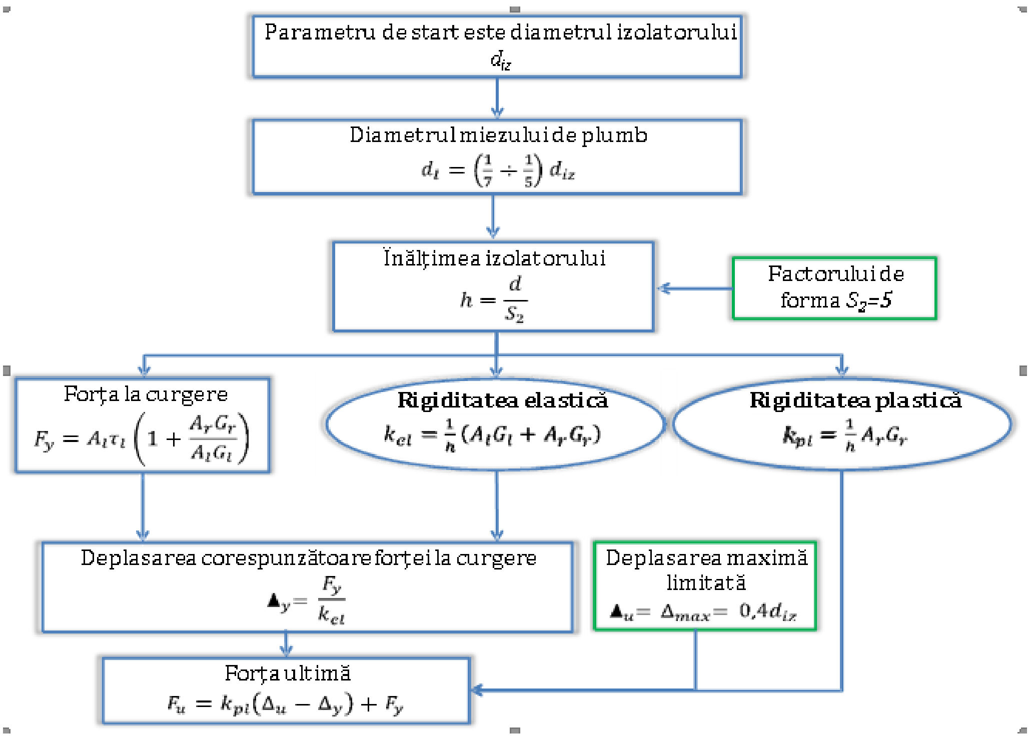

Figure 11. Algorithm used to determine the characteristics of an isolator

The evolutionary parameters of the presented genetic algorithm depend on the characteristics of the isolation system according to its dimensions. The determination of the dimensions of an insulator is made according to its behavioral force-displacement curve. For the application of the optimization algorithm, a bilinear curve of behavior of the seismic isolator has been chosen. elastic, Al and Ar are the area of the lead core and the area of the rubber respectively, kpl is the plastic stiffness, Fy is the flow force

- it is the flow resistance of the lead.

3.5. Case study 1

For the present study it was chosen to analyze a 10-storey structure consisting of beams, columns and reinforced concrete walls. Three calculation models have been developed: a model having a fixed base structure, a model with an isolated base structure, for which the isolators are dimensioned using the conventional calculation method and a model with the isolated base structure, the isolators being dimensioned using the method optimization based on genetic algorithms.

The building was subjected to a series of 3 accelerograms, one registered (INCERC Bucharest, Vrancea March 4, 1977) and the other two (Vrancea 1986 and Imperial Valley) modified to be compatible with the design spectrum, using the SeismoMatch program.

Nonlinear dynamic analysis was performed, in the first stage considering an average recurrence interval of 100 years, and in the second stage IMR was 475 years. The scaling factor for accelerograms, for which the 475-year IMR is 1.5, compared to the 100-year IMR =100 ani.

Lead-core seismic insulators were placed one below each pillar and two below the structural wall, all having the same properties. The behavior of the isolators was modeled using a bilinear model. The final displacement of the isolator was introduced in the calculation model using the gap element. This element allows the free movement of the structure up to a certain value, for which the movement of the structure in the direction of the connecting element is prevented.

In order to determine the dimensions of an insulator, the diagram presented in figure 11 was used.

In model 2 for the insulated base structure for which the insulators were dimensioned using the conventional method, it was intended to achieve a total isolation. This was not possible because the insulators could not reach the required displacement capacity so that the structure remains in the elastic behavior field. Using the insulation manufacturer's tables, a type of lead core insulator with dimensions dimension = 75 cm and dl = 20 cm was chosen.

For model 3 the dimensions of the isolators were determined using an optimization method using genetic algorithms. This method consists in finding an optimal solution that best meets the conditions of the objective function, which is given by the relative displacement at the tip of the structure for the three accelerograms.

The parameters that vary in this case study are the diameter of the insulator, the diameter of the lead core and the additional weight at the level of the shelf above the insulators. For these parameters, a domain of variation presented in the relations was imposed (17.).

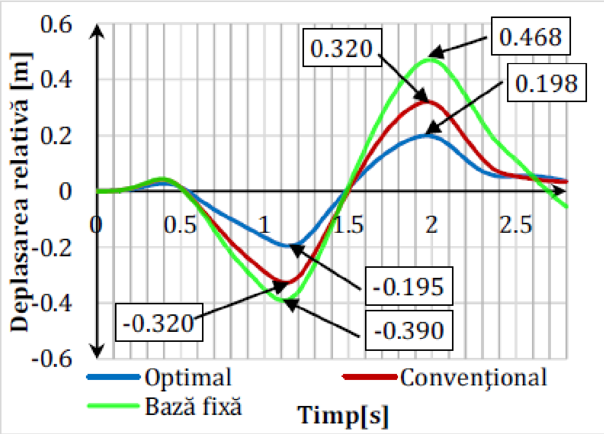

Figura 14. Variația în funcție de timp a deplasării relative pentru cutremurul de proiectare cu un IMR=475ani , INCERC -Vrancea 77

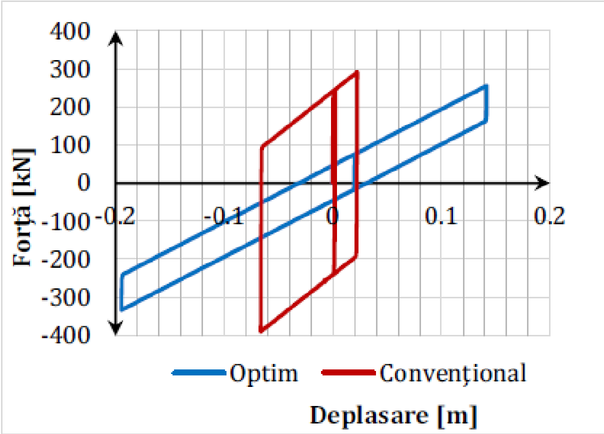

Figura 15. Curbele histeretice ale izolatorilor

It can be observed that the displacements relative to the structure with fixed base are 57% higher than the structure with optimally sized insulators. The difference between the structure with conventionally dimensioned insulated base and the structure with optimally dimensioned insulators is 38%. , the ultimate displacement having a small value at a large ultimate force Fu. The optimum insulator has a lower rigidity, with a lower flow force, but a much greater ultimate displacement. Although the energy dissipated by the optimum insulator is lower, it has greater flexibility which allows a requirement to be reached at a lower force relative to the conventionally sized insulator.

From the point of view of the additional mass, at the level of the deletion, it has been observed that a mass surplus is beneficial for the behavior of the structure at seismic actions. Following the use of genetic algorithms, a value has been established for which mass has a positive contribution.

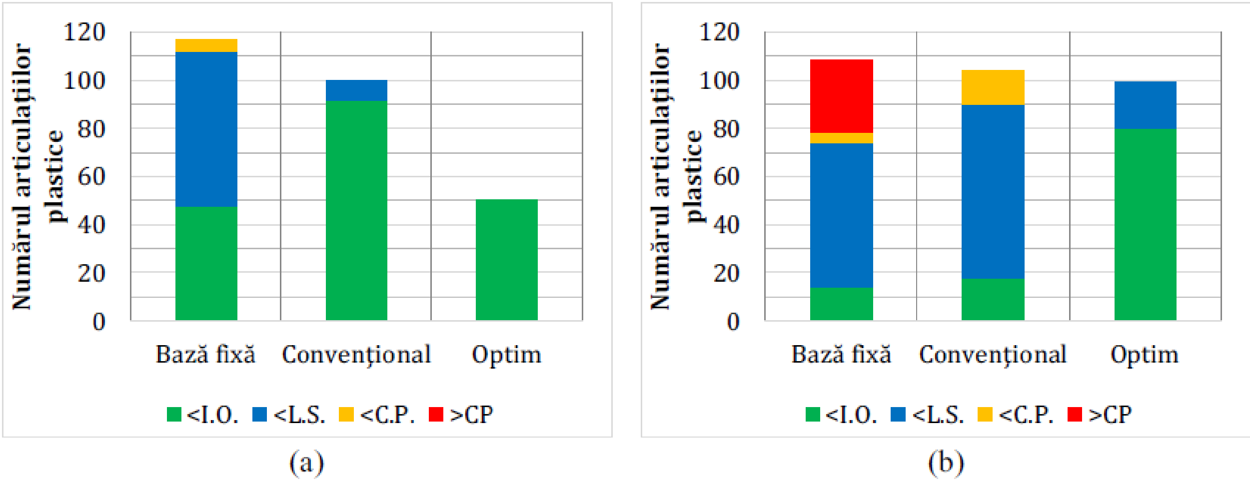

Figura 16. Numărul articulațiilor plastice pentru cele trei modele analizate
(a) IMR=100 ani (b) IMR=475ani

For a seismic action corresponding to an IMR of 475 years, the structure with fixed base presents some elements that reach collapse. In the case of the structure with conventionally dimensioned insulators, some elements reach the collapse threshold, while for the structure with optimally dimensioned insulators there are some plastic joints that at most pass only the immediate occupancy performance level.

In conclusion, for the case study analyzed, perfect isolation cannot be achieved, but an improvement of the structure response to the seismic action can be obtained by optimally sizing the isolation system of the support base. For the case study analyzed the improvement is observed at the relative displacement level, which was reduced by 60% compared to the fixed base structure, and 40% compared to the isolated base structure with conventionally sized insulation devices. As a result of this case study, it was found that the diameter of the insulator should be larger and the diameter of the lead core should be smaller. These dimensions must verify the inequalities presented above, thus resulting in low flow force, low lateral stiffness, but much greater displacement. Genetic algorithms are very useful in determining the characteristics of the isolation system. The optimally determined insulation system is more efficient than the classical insulated system for the analyzed structure and for the seismic action considered.

In order to be able to appreciate the efficiency of the genetic algorithms in the dimensioning of the seismic isolation systems of the support base, many more analyzes should be performed with different seismic actions and different types of structures, interpreting on probabilistic criteria. [8], [9]

3.6. Case study 2

For the case study, the analysis of a 11-storey structure made of beams, pillars and reinforced concrete walls was chosen. Four models of calculation were made: a model having a fixed-base structure, a model with an isolated base structure, the isolators being dimensioned using the conventional calculation method, a model with the base-based structure, the isolators being dimensioned using a de-optimization procedure based on genetic algorithms, and a model to which besides the dimensioning of the insulation system varies its positioning on the height of the structure.

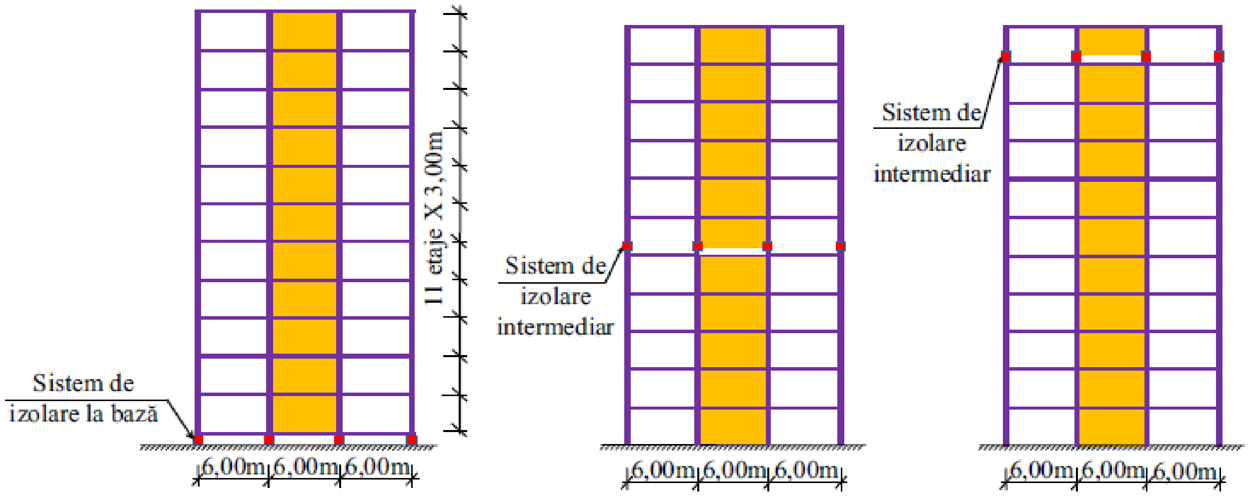

Figura 17. Elevația structurii și poziționarea sistemului de izolare

Nonlinear dynamic analysis was performed for two 100-year and 475-year mean recurrence intervals.

The characteristics of an insulator are obtained according to the algorithm of figure 11. presented in subchapter 6.4.2. .

In model 2 for the insulated base structure where the insulators were dimensioned using the conventional method, it was intended to achieve a total isolation. This was not possible because the resulting insulators could not reach the required displacement capacity so that the structure remains in the elastic behavioral domain. Using the insulation manufacturer's tables, a type of lead core insulator with dimensions dimension = 60 cm and dl = 12 cm was chosen.

For model 3 the dimensions of the isolators were determined using an optimization method that uses genetic algorithms. This method consists of finding an optimal solution that best meets the conditions of the objective function that is given by the relative displacement between the tip of the structure and the base of support for the three accelerograms.

Parameters that vary in this case study are the diameter of the insulator (diz), the diameter of the lead core (dl), the level of the houseplacing the insulation system (nI-S) and the additional weight at the level of the shelf above the insulators (pf).

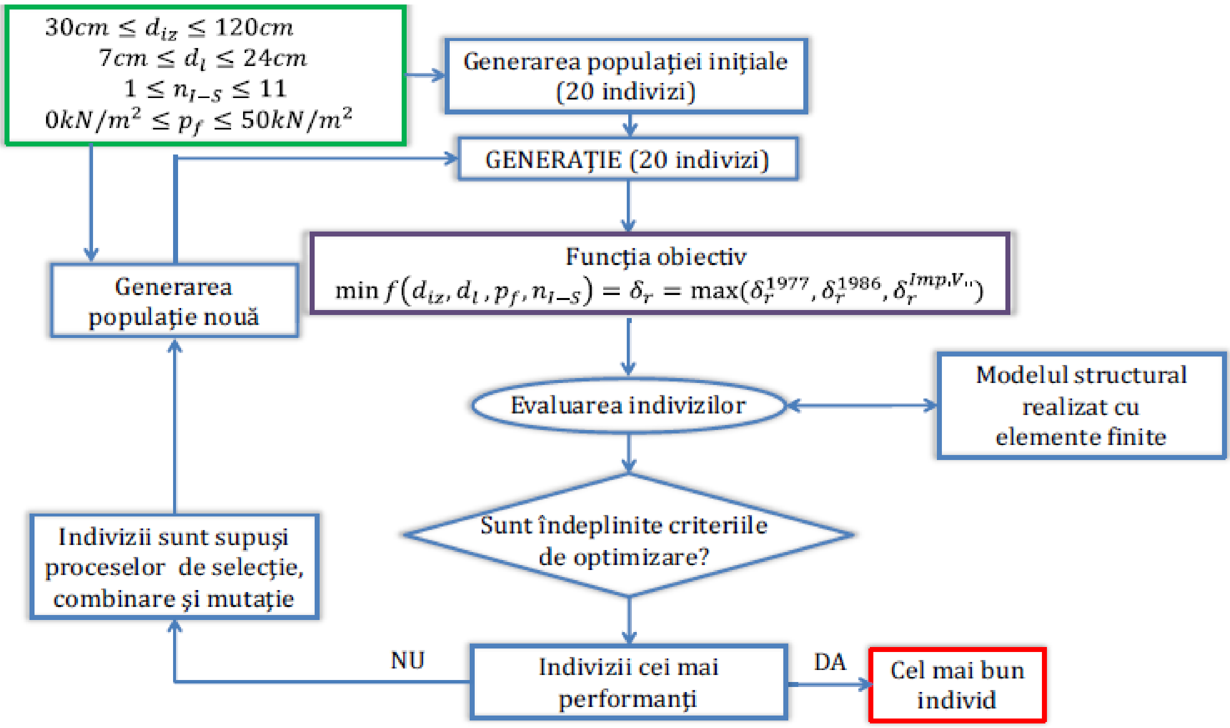

Figura 18. Schema de calcul a metodei de optimizare folosind algoritmi genetici

Following are the results obtained for the three models with insulation systems for a design earthquake corresponding to an IMR of 475 years.

It can be observed that the displacements relative to the structure with conventional dimensioned insulation system are 46% higher than the structure with optimally dimensioned insulators at the base. The difference between the structure with optimally sized insulators at the base and the structure with optimally sized insulators and level of insulation is 30%

It was found that the energy dissipated through the insulator intermediate for the conventional and the optimal model with base isolation is approximately equal. The areas of these diagrams are approximately equal, the differences being 10%. It is noted that the best response is obtained for the optimized structure, the hysteretic curve being much smaller. This can be explained by the tuned mass damper effect that the last level has on the behavior of the structure.

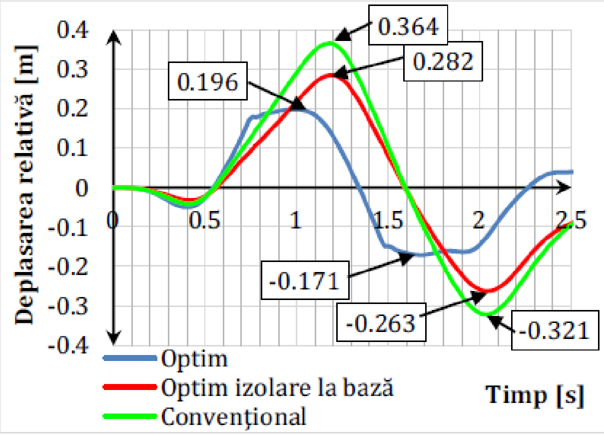

Figura 20. Variația în funcție de timp a deplasării relative pentru cutremurul de proiectare cu un IMR=475ani , INCERC -Vrancea 77

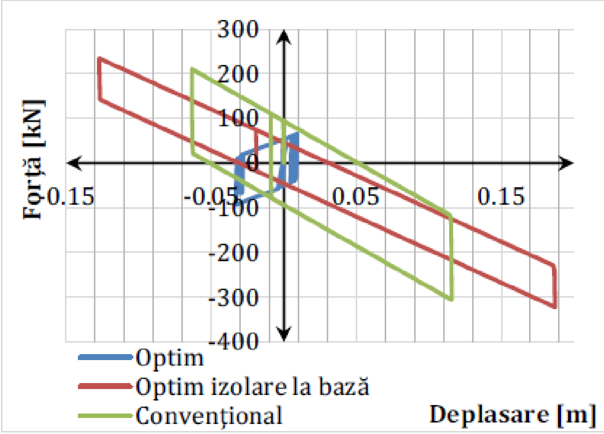

Figura 21. Curbele histeretice ale izolatorilor

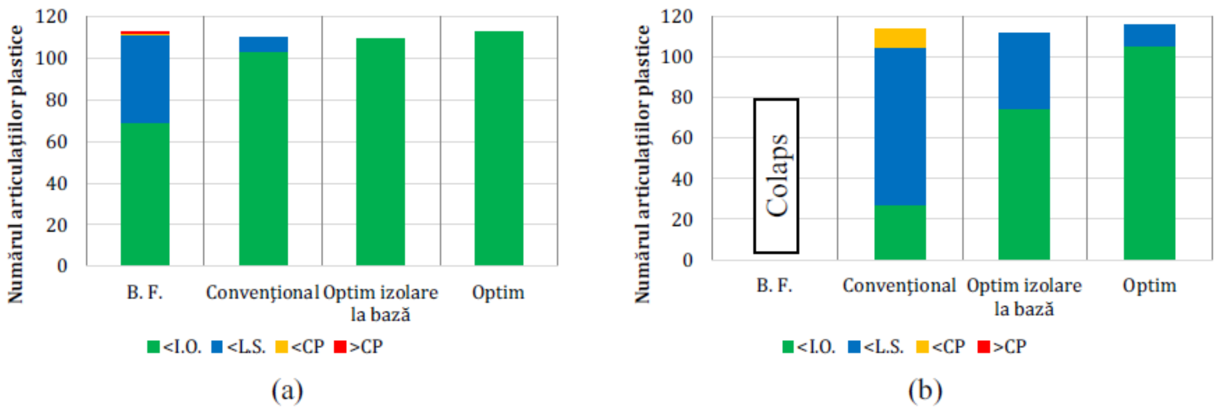

Figura 22. Numărul articulațiilor plastice pentru cele trei modele analizate (a) IMR=100 ani (b) IMR=475ani

For an seismic action corresponding to an IMR of 100 years the optimal structure and the structure with optimum insulation at the base have a behavior near the elastic limit. It is evident from figure 22. a.) The substantial improvement of the behavior of the structure for the cases where optimally dimensioned insulation systems are introduced. Basically the plastic spins from the dissipative elements are much smaller than in the case of the conventional insulated base structure and the fixed base structure.

For a seismic action corresponding to an IMR of 475 years the structure with fixed base reaches collapse. In the case of the structure with conventionally sized insulators, some elements reach the threshold of collapse, while the structure with optimally sized insulators at the base presents some plastic joints that go beyond the immediate occupancy performance level. Comparing the optimized structure with the optimally insulated structure it can be said that the number of plastic joints that appear after the level of immediate occupancy performance are reduced 4 times.

Basically, the most favorable behavior for this structure and for the seismic action chosen is given by the optimized structure to which both the dimensions of the insulators are optimized and the location of the insulation level on the height of the structure. Although the mass effect given does not show good results, due to the different content in predominant frequencies of the seismic actions, in the analyzed case the response of the structure is improved by positioning the insulators below the last floor level.

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