BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
Publicat de
Universitatea Tehnică „Gheorghe Asachi” din Iaşi
Tomul LX (LXIV), Fasc. 2, 2014
Secţia
CONSTRUCŢII. ARHITECTURĂ

DECREASING SEISMIC EFFECTS OF STRUCTURES USING BASE ISOLATION SYSTEMS

BY

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Received: June 11, 2014
Accepted for publication: June 30, 2014

Abstract. This paper presents many different energy dissipating dispositives that had been proposed to assist in mitigation the harmful effects of earthquakes on structures. The general details of the isolation systems were described, and a particular situation of an isolation system formed by elastomeric supports in the case study.

Romania is a country with a strong seismicity, mainly in Vrancea zone, and the Earthquakes affect a large part of the state. To prevent any further structural damages, calamities a new method of seismic prevention was developed, called base isolation systems.

A series of tests performed tacking into account various dynamic data, to obtain the mechanical characteristics and frequencies of the damper. Based on the component tests, the theoretical model (mathematical one) realized at a smaller scale, and the behavior of the damper was obtained.

General earthquake simulations were performed on a 6 stories reinforced concrete structure. The addition of supplemental dampers will reduce the structural response in terms of period of vibration and displacements. The analytical response concludes that the obtained values are smaller, therefore this methods is a very good seismic isolation solution for structures situated in seismic zones.

This method of seismic protection is a new developing method in Romania.

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Key words: elastomers; seismic isolation; base isolation.

1. Introduction

Earthquakes have been a difficult exam for any engineer, highlighting, first the conception and execution errors, secondly the objectivity of other ways and methods of design in seismic zones, and third the efficiency and a higher degree of security in construction exploitation. Conventional seismic design, during a seismic move, has an acceptable level of building performance. This level consists of the capacity for assimilation and dissipation of energy in the most stable manner and as for many cycles. Energy diffusion takes place, for example, in the special designed zones of the beams, where plastic joints are formed, and at the columns base, elements with an important role, but also in the system, which undertakes gravitational loads. Plastic joints are actually degradation concentration zones, which usually are difficult to rectify. As a follow-up, safety of life is ensured, detaining the structural collapse and froman economic point of view, the actual orientation in rational seismic design cannot be neglected. It is necessary on a bigger scale in new construction design and in existing building consolidation.

This article focuses on the events that happen during an Earthquake. The induced energy in a system depends actually on its dynamic characteristics, deformability and the energy dissipation capacity, in tight connection with the type of the action. This means that it is possible to establish optimal solutions to regulate and adapt structural characteristics, in such a way that a minimum of induced energy will be obtained, and the response implicitly.

2. Fundamental Principle of Base Isolation

The base isolation systems represent actually a special system. The fundamental principle of base isolation develops the fact that the seismic response of the structure is to be modified that the terrain will move beneath without transmitting the movement to the structure. The ideal system consists in a total separation of the structure from the terrain, but in reality, there are necessary a few contact zones between the structure and the terrain. Placement of the isolators leads to an increase of in the base flexibility in horizontal plan; in the purpose increasing the period of vibration in such a way, that the acceleration transmitted to the structure to be considerably reduces. Comparing the variation of the displacements and the forces that act on the structure it can be observed that with the changes of the period of vibration, to the increase of the displacements at the base level it corresponds a decrease in the forced that act on the structure (Fig. 1).

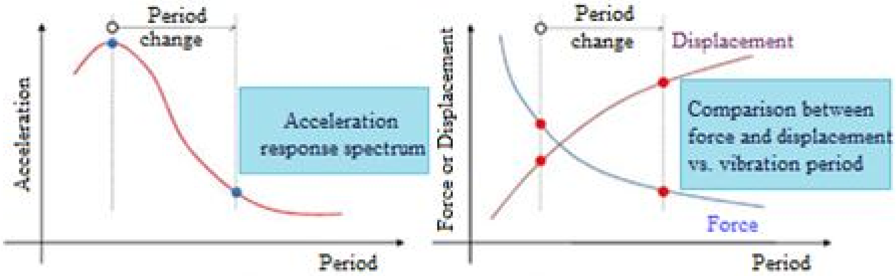

Fig. 1 – Theoretical principle of base isolation (Cruciat, 2013).

The seismic action in general has an increased degree of incertitude, in Romania the principal source is Vrancea. Observing that some differences appear between the movement characteristics for recordings of the same Earthquake on quite close emplacements, or in the same emplacements considering movements from the same source but at different time intervals. A large band of important frequencies characterizes especially the Earthquakes from Bucharest. For a better appreciation of the movement, beside the recorded accelerograms, it is necessary to compute a series of accelerograms.

By analyzing the seismic spectra, it results that to obtain efficiency by seismic base isolation it will be necessary to avoid the zones with maximum spectra.

Leading with the accumulated experience until now in construction base seismic isolation we can observe the change from the classic design conception in the sense that the work domain from the structures at a strong seismic action must be without incursions in the plastic domain, meaning that the intake of energy consumption structural or nonstructural, does not matter. The design stages of passive base isolated structures are differentiated by the isolation system used and by the construction type.

The base passive isolation systems could have or not elements that dissipate energy. Introduction of dissipaters must be correlated with the type of seismic action and maximum displacement admissible between the infrastructure and superstructure.

3. Analysis of Multi Degree of Freedom Structures (MDOF)

3.1. Artificial Accelerograms

According to the Seismic Code P100-1/2011 the artificial accelerograms are those computed based on a elastic response spectra for acceleration from the emplacement $Se(T)$. The elastic response spectra of the computed acelerograms must be appropriate to the elastic response spectra from the emplacement.

Based on the elastic response spectra for emplacement accelerograms the generated set of computed accelerograms must satisfy a series of conditions: a minimum number of three accelerograms; the arithmetic average of the computed accelerograms should not be smaller than the a_g of the zone. The interest zone of thee emplacement was Bucharest city; the zone will be characterizedby:

$$T_c = 1.60 \text{ s}, \ a_g = 0.24 \times 9.81 \text{ m/s}^2 = 2.35 \text{ m/s}^2.$$

The artificial accelerograms generated with the help of MATLAB program, obtaining a set two accelerograms. The variation in time of the accelerations for the two cases is presented in Fig. 2.

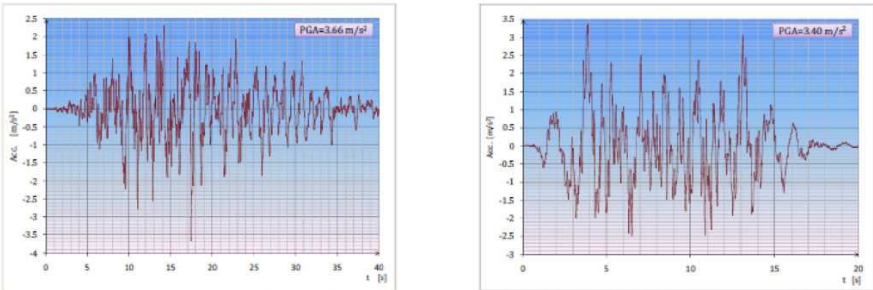

Fig. 2 –Artifficialaccelerograms 1 a_g = 3.66 m/s^2 and to the left and artifficialaccelerogram to the right with a_g = 3.40 m/s^2.

3. Analyzing Structures and Modeling Them

A series of three dwellings are utilized for analysis, with a difference in the fundamental period of vibration between them. Taking into consideration that the principal source of Earthquakes in Romania is Vrancea zone, considering the following periods of vibration:

$$T_1 = 0.5 \text{ s}, \ T_2 = 0.7 \text{ s}, \ T_3 = 1.0 \text{ s}.$$

The principal structural characteristic of the three building is that they are from reinforced concrete frames, with three equal spans and three bays. Considering the base relations from P100/2012 the following height regimes resulted corresponding to each period of vibration:

a) structure 1: 3 stories, H = 12 m;
b) structure 2: 5 stories, H = 20 m;
c) structure 3: 8 stories, H = 32 m.

To study the effects on structures of the base isolation systems, in case of seismic actions, the spatial models of the three structures were analyzed based on the Finite Element Method. To model the structure, and the dynamic computation, ETABS program was used, considering the following cases:

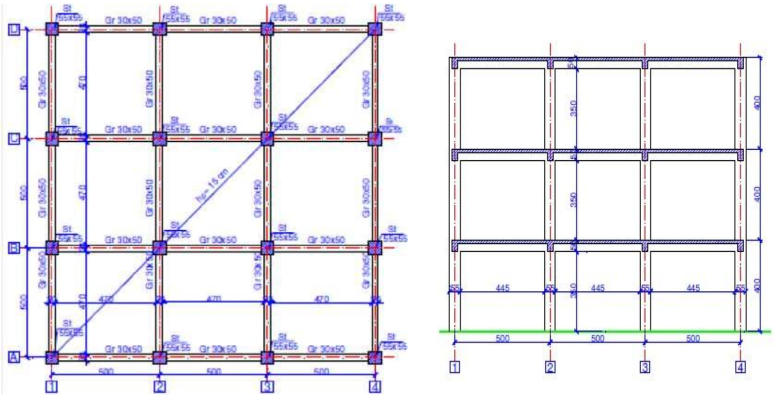

Fig. 3 – Current floor plan (left) and section (right) for structure 1.

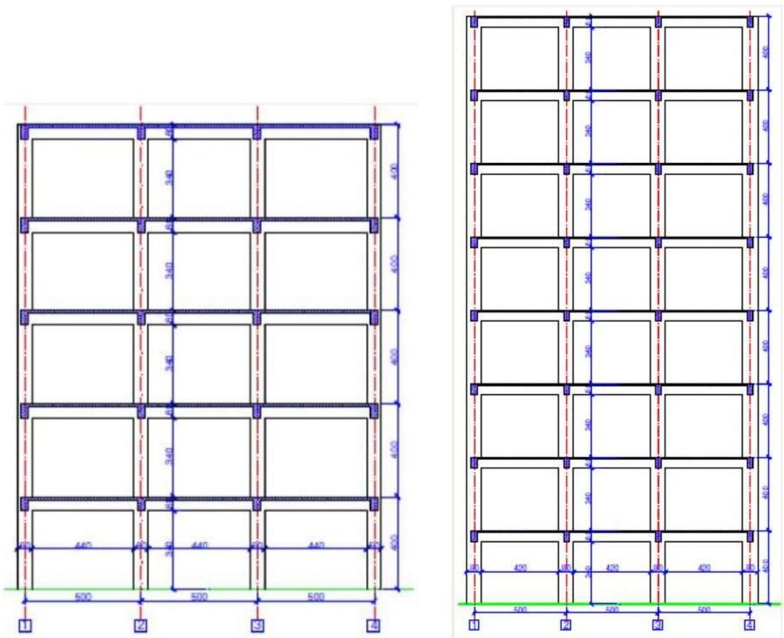

Fig. 4 – Section of structure 2 (left) and section of structure 3 (right).

Structure without dissipating systems;

Structure with isolated base (isolated system of the period of vibration equal to 2 seconds);

Structure with isolated base (isolated system of the period of vibration equal to 3 seconds);

As imagined the ground floor for structure 1 (Fig. 3) is also valid for structures 2 and 3 (Fig. 4), because the three structures have the same span and bay dimensions.

For modeling the base isolation system, in both variants being set on a foundation mat with a thickness of 70 cm, resulting a mass of the base M_b = 393.75 tons. The isolation system realized of 16 isolators with a high damping capacity (HDRB – High Damping Rubber Bearing), replaced for modeling with 16 link type elements considering an damping coefficient of 10% from the critical damping. The link type elements characteristics for the structures with the isolation system are found in the Table 1.

Table 1

Str,	Structure characteristics		Isolation system characteristics cu T = 2 s		Isolation system characteristics cu T = 3 s	
	T_i s	M_s tone	kN/m	tone/s		tone/s
STRl	0.54	825.4	152.02	47.875	334.23	31.92
STR2	0.67	1567.6	1209.9	77.02	537.72	51.35
STR3	1.07	2794.7	1966.8	125.21	874.13	83.47

The three structures were analyzed, corresponding to the four modeling cases, under the seismic action as follows:

a) Earthquake recorded movements;

b) INCERC Bucharest accelerogram, source Vrancea 1977, NS component;

c) INCERC Bucharest accelerogram, source Vrancea 1986, NS component;

d) Artificial seismic generated movements;

e) Accelerogram 1;

f) Accelerogram 2.

4. Base Isolation Systems

Comparing the response of the analysed structures, after the proposed seismic actions were realized at the relative displacement level of a node situated at the upper level of the structure, relative to the displacement at the base of the structure, the obtained results are presented in Figs. 5,...,10 for each structure type.

Structure 1 – with 3 leves, with T_s = 0.54 s;

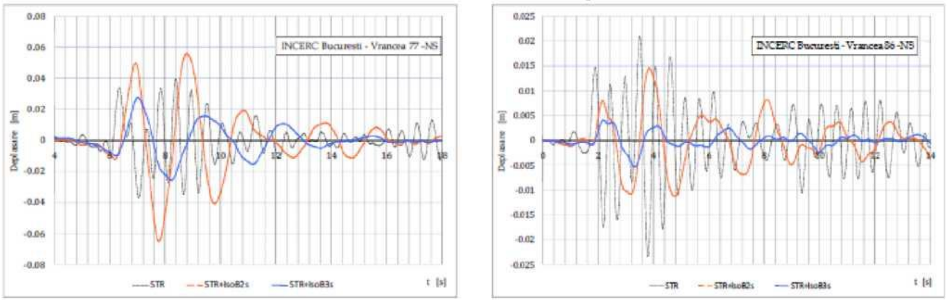

Fig. 5 – Top displacement with/without isolated base, INCERC Bucharest – Vrancea 1977 (left) and INCERC Bucharest Vrancea 1986 (right).

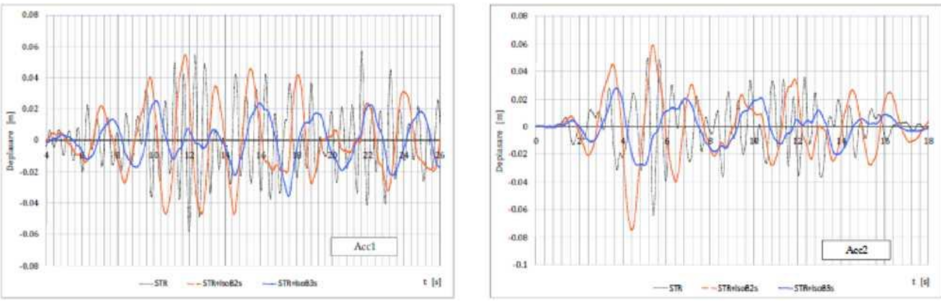

Fig. 6 – Top displacement with/without isolated base, Acceleration 1 (left) and Acceleration 2 (right).

Structure 2 – with 5 leves, with T_s = 0.67 s;

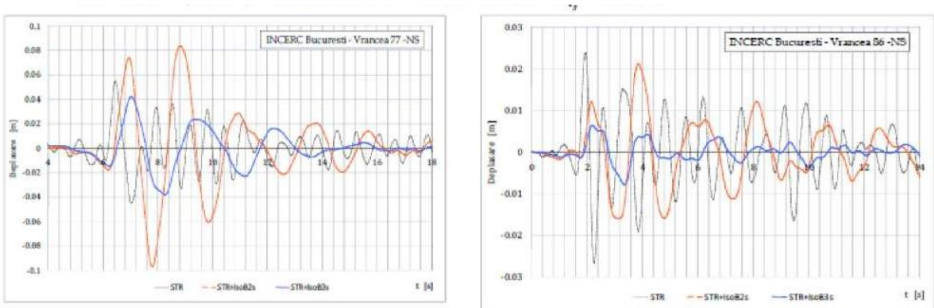

Fig. 7 – Top displacement with/without isolated base, INCERC Bucharest – Vrancea 1977 (left) and INCERC Bucharest Vrancea 1986 (right).

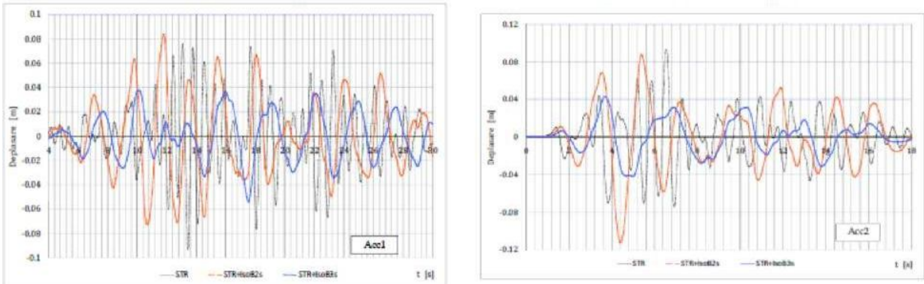

Fig. 8 – Top displacement with/without isolated base, Acceleration 1 (left) and Acceleration 2 (right).

Structure 3 – with 8 leves, with T_s = 1.07 s;

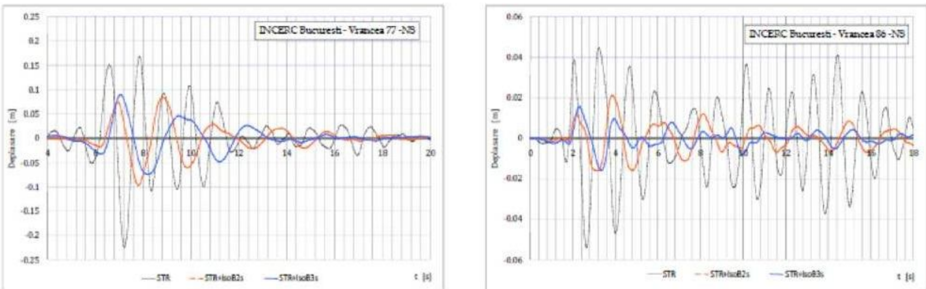

Fig. 9 – Top displacement with/without isolated base, INCERC Bucharest – Vrancea 1977 (left) and INCERC Bucharest Vrancea 1986 (right).

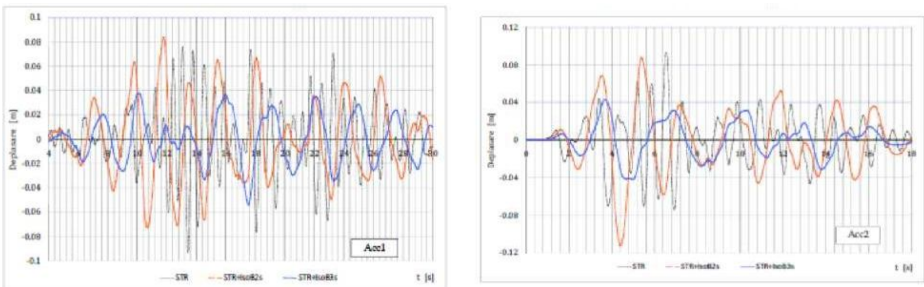

Fig. 10 – Top displacement with/without isolated base, Acceleration 1 (left) and Acceleration 2 (right).

5. Conclusions

The base isolation system, having the isolation period of two seconds, gad recorded the best response in case of structure 3, with 8 levels, were for all four considered seismic actions some considerable reductions of the maximum displacements were obtained and of the relative level displacement, approximately 50% (Vrancea Earthquake 1977) and 65 % (accelerograms 1 and 2). In case of the other buildings, it was observed a dependency of the structures to the earthquake frequencies (Figs. 5 left, 6 left right, 7 left). Another example may be structure 2 in case of the seismic action described by artificial accelerogram 1, were the period of vibration of the isolated system of 2.16 is overlapping with the period of vibration of the earthquake. With the exception of structure 3 and the cases observed, the isolated system offers a reduction in displacement of 25%.

Comparing with the classic design process were, by considering a behavior factor *q* between the limits of the Design Code P100/2012,when important reductions of the seismic design force can be obtained, admitting some structural degradations, which in some cases can make the structure unusable, the seismic base isolation system can be much more efficient.

REFERENCES

Cruciat R., Ghindea C., *Reduction of Seismic Action Effect on Buildings through Base Isolation Systems*. Sci. Bul. of the Techn. Univ. of Constructions, Bucharest, *3*, 46-53 (2013).

Seimic Design Code P100/2012

R.I. Skinner, W.H. Robinson, G.H. McVerry "An Introduction to Seismic Isolation" John WileysonsChichester. 1993.

F. Naeim, J.M. Kelly "Design of Seismic Isolated Structures" John Wiley & sons. New York.1999.

Kelly, T.E., Base Isolation of Structures. Design Guidelines, Wellington, New Zealand, ed:Holmes Consulting Group Ltd, 2001.

Mayes, R., State of the Art Technologies: Base Isolation and Energy Dissipators - Protection of Nonstructural Elements and Contents, San Francisco, SUA, 100th Anniversary Earthquake Conference Commemorating the 1906 San Francisco Earthquake,

[Web]http://www.1906eqconf.org/tutorials/StateoftheArtTechnologies_Mayes1.pdf, 2006

Lestuzzi, P., SimSeisme (Free software for earthquake engineering and structural dynamic).

[Web]http://imac.epfl.ch/Team/Lestuzzi/Software/SimSeisme/SimSeisme.html

SISTEME MODERNE PENTRU ATENUAREA EFECTULUI ACȚIUNII SEISMICE LA STRUCTURI

(Rezumat)

Cutremurele sunt potențiale evenimente naturale care amenința vieți, distrug bunuri materiale şi întrerup servicii necesare pentru menținerea vieții si a relațiilor

sociale. În proiectarea seismică convențională, un nivel acceptabil de performanța al cladirii, în timpul unei miscari seismice, constă în capacitatea intrinseca a structurii de rezistența de a absorbi şi disipa energie într-o maniera cât mai stabilă şi pentru cât mai multe cicluri. Disiparea energiei are loc, de exemplu, în zonele special realizate ale grinzilor unde apar articulații plastice şi la bazele stâlpilor, elemente cu un rol important, însă, şi în sistemul pentru preluarea încarcarilor gravitaționale. Articulațiile plastice reprezintă zone de concentrare a degradarilor care de obicei nu mai pot fi reparate. Ca urmare a faptului că siguranța vieții este asigurată, colapsul structurii este împiedicat şi, nu în ultimul rând, ca urmare a unor factori economici, orientarea actuala în proiectarea seismica rațională a structurilor nu poate fi înlaturata, ea utilizându-se pe scara larga atât la proiectarea structurilor noi, cât si la consolidarea celor existente.

Totuşi, în ultima perioadă, la nivel mondial, tot mai multe clădiri sunt proiectate să reziste la mişcarea seismică utilizându-se un concept relativ nou, şi anume acela de a introduce în structură dispozitive speciale cu rolul de a absorbi si/sau disipa energia indusa în structura de miscarea seismica. Aceste dispozitive pot fi introduse pentru a îmbunatați comportarea structurii din punct de vedere al ductilitații, conform principiilor prezentate mai sus, sau pentru a prelua în totalitate încarcarea seismică.