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SEISMIC BASE ISOLATION IN ROMANIA

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ABSTRACT

It is now generally accepted that a "*base isolated building*" will perform better than a conventional "*fixed – base building*" during moderate and strong earthquakes. This application of base isolation as means of earthquake protection, both for new and old structures, is a radical departure from the traditional approaches used in structural engineering. For the last 20 years, in many seismic countries, the concept of base isolation became usual and simple. Well understood worldwide, base isolation was received with a great deal of skepticism in Romania. The present paper intends to explain the reasons that stood behind such a situation and to answer the question: *how simple is it to be applied in this country?* The author wishes to emphasize some thoughts on the peculiarities of the seismic motion in Romania and, as a direct result, why the seismic isolation is still in its infancy in the country. Some elements related to the concept of resonance in case of seismic action and on the seismic isolation in Romania will be presented.

1. Introduction. Seismic "surprises".

In the history of earthquake engineering existed many seismic strong motions which have surprised the engineers and seismologists working in the field, through observed contradictions between: the provisions of the building design codes to seismic actions, the actual behavior of the buildings during strong ground motions and the seismic motion characteristics that were put into evidence by the response spectra.

The result of these inconsistencies was materialized in the implementation of major changes in the design codes and in the design process of resisting buildings to seismic actions. "*It is one of the great ironies of urban history that Mexico City, perhaps the largest city in the world, stands on one of the planet's most unstable subsoils*" (Tobriner, 1988). Many engineers, seismologists and scientific researchers were "*surprised*" that in the case of soft geologic medium beneath Mexico City, the earthquake that occurred on September 19, 1985, at an epicentral distance of about 400 km, has generated an unusual "*local amplification*" (factors up to 5). Of interest to engineers is the local amplification of ground motion imparted by Mexico City's soft lake-bed subsoil which resulted in a series of 0.5 Hz shock waves. It was not a

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"*surprise*", as the "*resonance*" of Mexico City's subsoil at a frequency of about 0.5 Hz had been observed during the earthquake of July 28, 1957, but its significance was not fully appreciated at that time. For engineers, the "*great surprise*" consisted of the behavior of buildings with very long eigenperiods. In conclusion, the *long distance* from the source to the principal area of destruction was *one unique feature* of the earthquake. A *second unique feature* was related to the subsurface conditions of Mexico City – in that there was substantial *amplification* of the low–frequency motions.

The January 17, 1994 Northridge and the January 17, 1995 Kobe earthquakes have represented the "*big surprises*" for the steel building design in the United States and Japan. Both earthquakes revealed the deficiencies that had existed for a long period of time in the design codes of the two countries and that had been applied up to the moment of the earthquakes occurrences. "*Seismic surprises*" associated to Romania earthquakes will be also summarized.

(a) November 10, 1940 Vrancea earthquake. Seismologists and engineers in the field of construction have been "*surprised*" by the two following aspects: *the seismic intensity* of the ground motion in the city of Bucharest area, at 160 km epicentral distance, and *the damage* of high buildings of flats, with 8...12 stories (the fact that one of these, which had totally collapsed, was considered as "an accident" and not "a rule").

(b) March 4, 1977 Vrancea earthquake. The following two aspects should be emphasized: seismologists and engineers in the field of construction have been "*surprised*" by the fact that the seismic motion has been so strong and, after processing the only accelerographic record obtained during the earthquake, foreign researchers have also been "*surprised*" by the configuration of the Romanian earthquake seismic spectra (a reconnaissance team professor hired by an international agency stated: "*such a motion is impossible*").

As the base isolation technique is still in its infancy in Romania, the author of this paper hopes that at the next occurrence of a strong seismic motion in this country, the behavior of the buildings "base isolated" won't represent "*another surprise*".

2. Short on Romania legislation related to seismic isolation

The first Romania legislative action related to seismic base isolation occurred in 1992, when the Ministry of Public Works and Territory Planning enforced the "Code for Aseismic Design of Residential Buildings, Agro-zootechnical and Industrial Structures" (P100-92). In Chapter 2, entitled "Principles for aseismic design" item 2.2 (iv), it was stipulated: "The building aseismic design has the following *objectives: i...(iv) to provide, in certain cases, energy dissipating devices, which may have a favorable influence on the seismic response of the structure*". Until 2004 the above paragraph was the only resolution with reference to the subject "*seismic base isolation*". In 2004 a guide and a methodology on the subject were approved by the Ministry of Transportation, Construction and Tourism (M.T.C.T.): "*Guide for the design of the passive seismic isolation systems for buildings*" and "*Methodology for the analysis of passive protection systems. Self-adaptable buildings to seismic actions*".

The latest legislative action is that of 2006, when M.T.C.T. enacted the code named "Code for seismic design" (P100-1/2006). Chapter 11, entitled "*Base isolation*", is a translation of Chapter 10, having the same title, of the Eurocode 8.

3. A geophysical approach on the Romania seismicity

Seismic hazard for almost half of the territory of Romania is determined by the Vrancea seismic region, which is located at the sharp bend of the Southern Carpathian Arc (a well-defined seismic region of Europe with unique properties). The Vrancea earthquake zone is at the contact between the following tectonic units: the Eastern European plate to the North and North-East, the Black Sea microplate to the South-East, the Moesian microplate to the South and South-West and the Intra-Alpine (Panonian-Carpathian) microplate into the North-West. The seismicity is concentrated in a high-velocity, narrow focal volume in the depth range 60÷200 km. A relatively high seismic energy is persistently released (three shocks with seismic magnitude $M_{G\text{-}R}$ not less than 7 during the past century) by a seismogenic process that is still far from being fully understood. In spite of the small dimensions of the earthquake zone and the complicated geometry of the Carpathians with their sharp bend in the Vrancea region, simple plate tectonics concepts have tentatively been used for explanation, leading to the idea that a slab-like continuation of the Black Sea plate is subducted under the Eurasian plate. Further observational studies are necessary to substantiate or change these ideas. Table 1 summarizes the magnitude values and the foci depths for the strongest subcrustal ground motions that have occurred on the Romanian territory and originating from the Vrancea region.

Table 1. Recent subcrustal strong earthquakes in Romania.

Date	Latitude/ Longitude	Focus depth (km)	$M_{G\text{-}R}$	M_W
November 10, 1940	45.80°/26.70°	133	7.4	7.8
March 4, 1977	45.78°/26.78°	93	7.2	7.5
August 30/31, 1986	45.53°/26.47°	133	7.0	7.2
May 30, 1990	45.82°/26.90°	91	6.7	7.0
May 31, 1990	45.83°/26.89°	79	6.1	6.3

The seismicity of Romania is mainly due to the activity within the Vrancea region that delivers in the average, per century, more than 95% of the entire seismic energy for the country. This source zone has direct influence over about half the territory of Romania, producing high intensity earthquakes. The upper limit of seismic magnitudes for Vrancea earthquakes is considered to be $M_W \approx 8.0$.

4. Basic instrumental data

The first strong motion accelerogram recorded in Romania was obtained on a SMAC-B type strong motion accelerograph, during the March 4, 1977 Vrancea earthquake at ground level, in the soil conditions of Bucharest.

The peak ground acceleration values in the N-S, E-W and vertical directions were 0.20 g (PGA = 194.9 cm/s^2), 0.16 g and 0.10 g, respectively. A glance at the record shows that the long period components were predominant, aspect that surprised the engineering community of Romania, although engineers were acquainted with the code proposal written by engineers Emilian Titaru and Alexandru Cismigiu in 1960 at the 2WCEE (Japan). So, one can consider as birth date of the instrumental earthquake engineering in Romania the date of March 4, 1977. It is interesting to note that the shape of the spectral accelerations was very different of that generally assumed in the code in force at that time. It must be mentioned that the elastic spectra shape had been imported from the Soviet code SN-8-57, characterized by a maximum dynamic amplification factor $\beta_0 = 3.0$ and a corner period of response spectra $T_C = 0.3$ s, which, at its turn, corresponded to the 1940 El Centro earthquake spectra. In order to compare the acceleration response spectrum of the March 4, 1977 earthquake N-S component with the acceleration response spectrum of the N-S component of the 1940 El Centro earthquake, the latter was normalized to the same peak value and plotted on the same diagram. The shapes of the spectral accelerations of these two earthquakes are very much different from each other. *The highest values of periods occurred in the range of 1.0...1.6 s for the N-S component, and of 0.7...1.2 s for the E-W component.* Taking into account the above-mentioned values of the dominant periods, it was to be expected that the damage should occur especially for the flexible buildings, having fundamental eigenperiods of vibration of about 1 s or more.

During the 1986 earthquake, the PGA values in Bucharest ranged between 0.06 g and 0.16 g (for the N-S component) and between 0.04g and 0.11g (for the E-W component). The 1986 INCERC record, at the same location as in 1977, had PGA values of 0.10 g (E-W component) and 0.09 g (N-S component). The zone of highest spectral values, corresponding to periods exceeding 1.0 s (similar to the 1977 event) got a secondary importance for this earthquake. A variety of PGA values, ranging between 0.07g and 0.14g were reported during the main shock of the 1990 earthquake in Bucharest. What surprised was the fact that many records of the main shock on the E-W direction were stronger than on the N-S direction (opposite to the previous two seismic events). More than that, the zone of highest spectral values, corresponding to periods exceeding 1.0 s totally disappeared for the seismic event of May 30, 1990.

The characteristics of the strong motions recorded in Bucharest during the 1977, 1986 and 1990 Vrancea earthquakes in different stations are summarized as follows:

- PGA (cm/s^2): 215 (1977); 60 to 160 (1986); 70 to 140 (1990);
- zones of highest spectral values: 0.9 and 1.5s (1977); 0.7 to 1.1s (1986); 0.25s (1990);
- predominant component: N-S (1977); N-S (1986); E-W (1990).

Taking into account the subject of this paper the following question naturally results: *why these important changes have occurred?* Examining the ensemble of available instrumental data and the response spectra of absolute acceleration it resulted that a secondary spectral peak observed at INCERC station, for the 1986 event, appeared as such *for all stations* where records were obtained. It was also observed that a spectral amplification for long periods (as in the 1977 and 1986 seismic events) was absent *for all stations* in the case of the 1990 seismic event. It must be specified that these modifications of spectral contents of ground motion, which occurred in spite the fact that there was no variation in time of the local geological conditions, lead to the conclusion that they could be due only to the *modification of source mechanism* from one event to the other (Sandi, Vlad, and others, 2004).

5. Peculiarities of Vrancea strong motions

The intermediate foci identified until present day are quite reduced as number, being located in the Hindu Kush (unpopulated area at the Pakistan – Afghanistan border) and in Romania (a very dense populated area).

A first peculiarity that differentiates earthquakes occurring within the Romania territory from earthquakes occurring in other parts of the world is the *focal mechanism* (the focal depth, the frequency content of the seismic motion, the seismic waves' directivity, the occurrence rate of the strong motions, the returning period etc.).

The *second peculiarity* specific to the Romania territory is given by the *depth of the sedimentary layer*. At the beginning of the 60's, engineers E. Titaru and A. Cişmigiu together with the geologist Radu Ciocârdel, have studied, prepared and published at the 7th Congress of Carpatho-Balkan Geological Association aspects related to the seismogenese of the Romania territory and have established geological-technical criteria for dividing the country into seismic zones. One of the most important ideas emerged as a result of these studies was the one referring to the achievement of a graphical image of the thickness of the sedimentary rocks deposit allover the Romania territory. Later on, having in mind the ideas of engineer E. Titaru, a group of researchers published in 1972 a "*geological map*" that contained the depths of the sedimentary layers on the Romanian territory. This map shows that the only "hole" in the world, filled with a sedimentary deposit of 6.5 km thickness, is located in the Vrancea seismogenic zone (as a comparison, the thickness of the sedimentary layer in Mexico City varies around 80 m). In Bucharest, the thickness of the sedimentary rock deposit is of about 1.5 km.

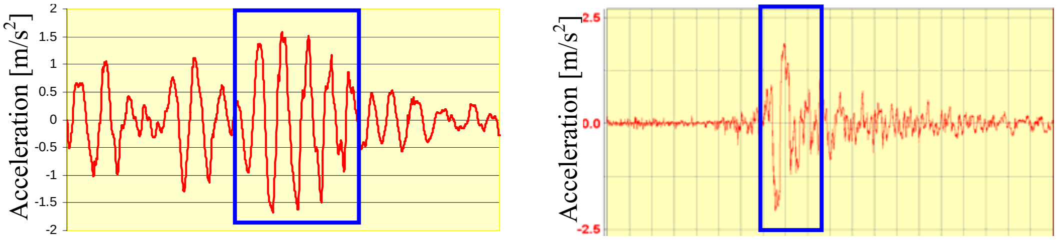
The above-mentioned two peculiarities make the important difference between the incidences of earthquakes on the Romanian territory in comparison with the incidence of earthquakes in all the others territories worldwide. Otherwise, earthquakes that occur in Romania have a *unique character*, and for this reason, they seem not to be of the highest interest for researchers from other countries. The city of Bucharest is placed at about 160 km from the epicentral zone in the Vrancea region. Usually earthquakes do not generate significant damage to buildings located at such epicentral distances. Anyway, the March 4, 1977 earthquake caused major damage to buildings in Bucharest and 32 of them collapsed (31 blocks of flats).

The third very important peculiarity of the Romania earthquakes consists of the "*persistence*" of the Vrancea foci position, which is governed by the subduction process of the Black Sea microplate under the Intra-Alpine microplate. This aspect is specific for the Romania earthquakes, as other earthquakes have foci and focal depths always different. The persistence of the earthquake foci in Romania is a peculiarity that pertains to the Vrancea seismogenic zone.

6. The concept of resonance in case of seismic action

The September 19, 1985 Michoacán earthquake and others like it revealed a fundamental principle in seismology: seismic risk, or damage done by an earthquake, depends not only on the seismic event itself but also on the ground that underlies the buildings.

In most publications devoted to the study of the response of structural systems to dynamic actions, the *phenomenon of resonance* is defined (in a wider sense) for periodic motion, respectively (in a strict sense) for a motion described by the sine function with respect to time, in terms of equality between one of the frequencies (dominant) and the natural frequency of the dynamic system. Implicitly or explicitly, the basic definitions refer to strictly periodic motion cases which take place infinite in time (from $t = -\infty$ to $t = +\infty$). It is considered that this method of definition is not complete, because the phenomenon of resonance occurs if the following conditions meet up: firstly the equality of one of the significant frequencies of excitation with one of the natural frequencies of the structural member, or of the excited system, and secondly the number of cycles of the motion (Fig. 1) which are repeated until a maximum amplification level is reached. Repeating the number of cycles of movement increases the amplification effect from cycle to cycle.



(a) 5 cycles (b) 1.5 cycles

Figure 1. The 1985 Mexico City (a) and 1977 Vrancea (b) earthquakes accelerograms.

For a proper understanding of the phenomenon of resonance the following four remarks should be considered:

- *Remark 1*: the repetition of cycles of motion (the increase of number of cycles) has as effect a gradual increase of values of the kinematic characteristics of the motion of the element, or of the excited structural system.
- *Remark 2*: the more an approach of a frequency of the exciter and of one of the natural frequencies of the structural member (or of the excited structural system) occurs, the kinematic characteristics of the motion (displacements, velocities and accelerations) will be amplified;
- *Remark 3*: the amplification factor of the kinematic characteristics of the motion of the element, or of the excited structural system, is higher as its damping property is lower (steel around 2%, concrete around 5% etc.);
- *Remark 4*: when repeating the action, in the stage when a frequency of the excitation equals the natural frequency of the element, or of the excited structural system, the amplification of the kinematic characteristics of its motion reaches a maximum value (practically), after a certain number of repeated cycles, depending on the damping characteristic, namely the fraction of critical damping (there is an asymptotic approach to the amplitude of pure resonance); thereafter, as many cycles of motion would follow, the amplification would practically remain at the same level, that is the maximum one.

The response of a structure to the irregular and transient excitation of an earthquake will obviously be much more complex than in the simple harmonic steady-state motion. In the case of seismic action, to speak of *resonance* requires to be considered, simultaneously, three subsystems: the lithosphere, the sedimentary deposit and the existing building stock located above it, as follows. Each seismic event generates several wave trains, well identified on station records. During the seismic waves' propagation, these wave trains occupy distinct positions in the successive time instants. In case of a Vrancea earthquake such a position can be considered that of Bucharest city, located at 160 km from the epicenter. Because different types of waves and waves of different frequencies travel at different speeds away from the earthquake source area, they become organized into groups traveling at similar velocities. The *travel time* of a seismic wave from a source to a receiver depends on the seismic velocities of the Earth material traversed, the distance from the source to the receiver, and the geometry of boundaries separating Earth materials. A receiver commonly records more than one arrival of seismic energy, because the energy may radiate from the source as various body and surface waves, and because the body waves are refracted and reflected along different paths when they encounter boundaries.

The seismic waves generated by a focal disturbance in the Vrancea region and propagated by a granite layer of the lithosphere, had initially contained many different frequencies (or periods), but those that survived the 160 km journey to the city of Bucharest are the ones with relatively long periods of 1.0 to 1.6s (or frequencies of 0.63 Hz to 1.0 Hz). Incoming earthquake waves having such range of periods have excited the existing 1.5 km sedimentary deposit. The structure of the sedimentary deposit can be imagined as consisting of uniform parallel layers, starting with the surface layer until the base layer as the nth layer. Otherwise, the sedimentary deposit can be considered as a "dynamic system" having "n" degrees of freedom and, as a direct consequence, "n" eigenmodes characterized by "n" eigenperiods and "n" eigenshapes. The eigenperiods (or the eigenfrequencies) of the sedimentary deposit depend on the size and its shape and on the amount and composition of the sediment it contains. The eigenperiods and the eigenvectors of the sedimentary geological deposit have a decisive influence on the dynamic filtering of waves that are propagated and on the phenomenon of amplification of seismic effects produced at the surface of the Earth. The most important aspect related to the influence of local geological conditions is "*the spectral content of the seismic motion*". Among the unlimited number of eigenmodes of the sedimentary deposit, the most excited is the eigenmode whose eigenperiod is situated near, or is equal to that of the seismic waves arrived through the lithosphere (in the case in discussion $T \cong 1.5$ s). One can say that the seismic waves in the granite layer of the lithosphere excite the sedimentary deposit with the same values of the periods that they had when they reached Bucharest location. When the sedimentary deposit is stimulated at one of its resonant periods, the amplitude of the seismic motion is significantly increased. This effect can be associated to a phenomenon called "*partial resonance*", or "*first resonance*". Moreover, the sedimentary deposit continued to vibrate at modal periods, even when the underlying seismic wave train passed on. As a result of the sedimentary deposit amplified motion at the resonant period equal to 1.5 s, all buildings in Bucharest are subject of a vibration also characterized by a period of 1.5 s. Those buildings of the existing stock that shake in step with the sedimentary deposit enter into a second process of partial resonance, or the *second resonance*, while the others with shorter eigenperiods will be less affected due to more reduced values of seismic forces. This coincidental match of oscillation frequencies, known as "*double resonance*" is potentially very destructive, and in most cases leads to the total collapse of the building.

The designer must be fully aware of the importance of the fact that the effect of seismic waves *arrived* through the granite layer of the lithosphere into a location is transferred with "*the same period*" both to the sedimentary geological deposit and to the existing buildings of the surface. In other words, in a certain location, the granite layer of the lithosphere, as well as the sedimentary geological deposit, together with buildings situated at its surface, are subject of a simultaneous motion characterized by same periods. Finally, a tentative for the definition of the "*resonance phenomenon*" in case of seismic action is given:

a) The "*total resonance phenomenon*" can be defined based on two criteria: the proximity or identity of a frequency/period of the seismic action and of a frequency/period of the building and the achievement of a certain number of repetition of the cycle of maximum intensity of the seismic motion, depending on the viscous damping characteristic of the environment in a particular location.

b) The "*partial resonance phenomenon*" occurs when only one of the two criteria is met, usually the proximity or the identity of the frequencies and the second one is only partially fulfilled (instead that a number of repetitions of cycles of seismic motion is made leading to a maximum amplification factor no matter how many cycles it would take to stop it growing, a smaller number of repetitions is done without reaching the maximum amplification factor).

That's why one cannot speak about a "*predominant period*" of an area, or of a site; the result of analyses performed put to evidence the modification of "*dominant periods of ground motion*" from one seismic event to the other (Sandi, International Symposium, 2008).

7. Seismic isolation in Romania

For all other countries, for the last 20 years, the concept of base isolation became quite simple. Is it simple for Romania too? The efficiency of an isolation system in *reducing seismic forces* in a building depends on the *lengthening of its fundamental period*, which is associated with *large displacements at the isolation level*. As it is already known, the use in the design process of the base isolation concept is widespread in countries where strong earthquakes originate from foci in the upper 10 km, and only few are as deep as 15 km. In Romania *intermediate focus earthquakes* (60 to 300 km) occur. It is important to mention, once more, that the sedimentary basins in populated regions have significant depths.

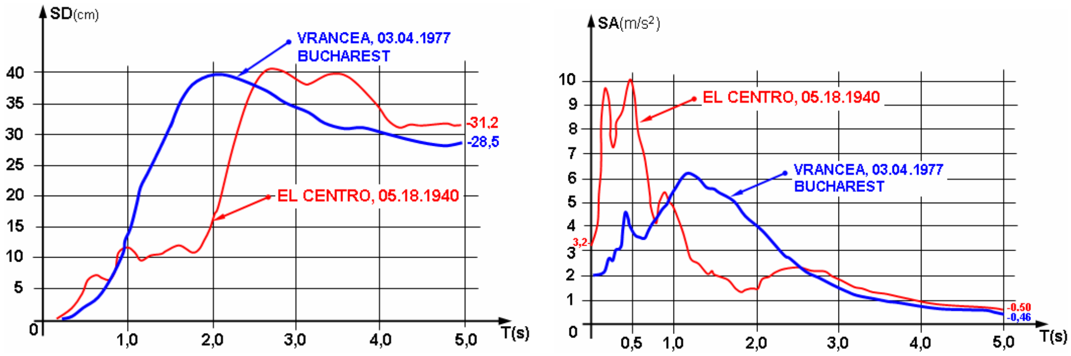
This is the *first characteristic* of the strong Vrancea earthquakes and its direct effect consists of the fact that the corner periods of the response spectra can be about five times greater than the corner values of other earthquakes worldwide.

The *second important characteristic* refers to the number of cycles of a seismic wave in the lithosphere, having the same period. This number of repetitions of almost identical cycles is also transmitted to the sedimentary geological deposit and to the building stock above it (Fig. 1).

In Fig. 2,a are presented by comparison the SD spectra for the March 4, 1977, Vrancea earthquake ($H_F = 93$ km; PGA = 0.2 g), and the May 18, 1940 El Centro earthquake ($H_F = 16$ km; PGA = 0.32 g). One can notice that the displacements in case of Vrancea earthquake computed for the city of Bucharest, start being large and very large for values of periods T longer than 1 s. Instead, the SD spectrum computed for the El Centro earthquake has reduced values for periods in the range 1÷2 s, which start to grow after the period value equal to 2 s. In Fig. 2,b are presented for comparison the SA spectra for the above mentioned earthquakes. One can notice that the accelerations in case of Vrancea earthquake, computed for the city of Bucharest, have large values in the range of periods up to 2.5 s. Instead, the SA spectrum computed for the El Centro earthquake shows that the acceleration values strongly diminish for periods longer than 1.2 s.

The goal of base isolation is to *reduce the seismic forces* that are exerted by an earthquake on a building structure. That's why the building which is going to be seismic isolated must be "placed" in a zone of the SA spectra with convenient periods. At the same time, values of horizontal displacements that the isolators must undergo should be taken into consideration. So, at the design of a "seismic isolation" for "El Centro" type earthquakes, the seismic forces can be reduced by placing the building in the period range of 1.2÷2 s. At the same time, for this period range, the horizontal displacements that the isolators must undergo are reduced, of about 10...12 cm. In contrast with the above presented case, the design of a "seismic isolation" in Bucharest, for "Vrancea" type earthquakes, the seismic forces can only be reduced by placing the building in the period range over 2.5 s.

The straight consequence of being obliged to place the building in the zone of very long periods consists of the fact that the isolators that are to be used must assure horizontal displacements of the order 40...45 cm. It should be noticed that the SA spectrum for the Vrancea 1977 earthquake was computed for 0.2 g, value that recently was increased to 0.24 g, and which is to be again increased for a return period of 475 years.



(a) (b)

Figure 2. The SD and SA spectra, for the 1977, Vrancea and the 1940, El Centro earthquakes.

In the case of buildings *without seismic isolation*, the fundamental principle where from all the protection measures against earthquakes result, is the achievement of a high capacity of ductility. This principle was formulated by Kiyoshi Muto as follows: "*enough strength and high ductility*". In the case of buildings *with seismic isolation*, a paraphrase of the Muto principle can be formulated as follows: "*very little strength, but very long fundamental period is necessary*". For this reason, in the design process of a building with seismic isolation, the designer must follow an official document that establishes some limits both for a minimum strength capacity and for a minimum ductility capacity. The ensuring of a strength capacity and of a ductility capacity could be compensatory for the uncertainties that still persist in connection with the characteristics of the seismic action in Romania (today there is a single record of the 1977 *strong* earthquake and several records that are not very edifying for the *weaker* earthquakes of 1986 and of 1990). The lack of coherent legislation (P100-1/2006) and the uncertainties connected to the characteristics of seismic action represent for a seismic isolation designer important risks. To eliminate these risks some measures are necessary in the design process of a new seismic isolated building, as well as in the strengthening design of an existing one.

The second principle refers to seismic isolation devices. These must allow large displacements of about 40÷45 cm, besides the safety reserves. If by structural analysis it turns out that the seismic isolation devices must allow horizontal displacements equal to 40 cm (for safety reasons they should allow displacements of even 60 cm). That is why it is necessary to clarify the use of seismic isolation devices in Romania. Towards this aspect, one must know if these devices can assure the same vertical level during the motion of the base of the building superstructure. If these devices have also displacements in a vertical plane (like in the case of the neoprene devices), then, as a result of the forces transmitted by the superstructure, they can have displacements with different values. For an efficient use, these seismic devices must have such configurations in order not to affect the behavior of the superstructure by supplementary and differentiated vertical displacements.

9. Short on the first case of seismic isolation in Romania

At present, the first case of base seismic isolation of a building in Romania is accomplished. The building in discussion was erected at the beginning of the 20th century, when no seismic legislation existed in Romania. It has supported all the major Vrancea earthquakes of 1940, 1977, 1986 and 1990, at present being weakened and highly susceptible to collapse during future severe earthquakes. The involvement of the author consisted of performing an instrumental investigation by the ambient vibration method using Kinemetrics equipment. The instrumental research was carried out in order to provide the designer the following elements: the verifying of the accuracy of the structural models of analysis used in design of the base isolation rehabilitation of the building, and the identification of structural dynamic properties of the whole building. The philosophy behind the installation of base isolators was to lengthen the fundamental eigenperiod of vibration of the protected structure, so as to reduce the base shear induced by the earthquake, while providing additional damping for reducing the relative displacements across the isolators themselves. This is why most seismic design codes suggest the use of base isolation systems that have the dual function of period lengthening and energy dissipation. 80 SEP isolators having an exterior diameter of 750 mm with the total height of 400 mm, consisting of 33 steel plates and 34 layers of natural rubber, together with 18 seismic dampers, were mounted by Taylor Devices Inc.

10. Some conclusions and proposals

a) The specific characteristics that differentiate the Romania territory from other seismic zones of the globe are: *the foci depths, the persistence of the foci and the depths of the sedimentary geological deposit* (nowhere in the world exist such deep sedimentary deposits as in Romania); these characteristics create the major differences that exist between the seismic motions that occur in Romania and the seismic motions that occur in all the other zones of the world. That's why the seismic isolation of buildings in Romania is strongly dependent on the seismic peculiarities of the seismic action generated by Vrancea earthquakes.

b) Risks considering the safety of the buildings to which "*base isolation*" method will be applied are generated by: *insufficient knowledge* of some of the characteristics of intermediate earthquakes that occur in Romania and *insufficient knowledge* of seismic isolation devices related to peculiarities of the Vrancea strong motions.

c) The application of base isolation, both for new and old structures, is a radical departure from the traditional approaches used by structural engineers. Seismic isolation allows the structural engineer to control damage in earthquakes for both building and its contents (Vlad, 2008).

d) In the design process of a building with seismic isolation in Romania two principles must be considered, which means that a "*spectral position*" must be assured. The *first principle* refers to the assurance of a *spectral position* that should be characterized by a vibration fundamental eigenperiod long enough, so that the resulting seismic accelerations be as reduced as they can (in case of Bucharest even longer than 4 s). At the same time, the achievement of these long periods imposes *the second principle*, that the seismic isolators assure displacements with very large values (more than 45 cm).

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