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A MODERN SYSTEM FOR BUILDING UP REINFORCED CONCRETE STRUCTURES

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Abstract

The article presents a modern method of building up constructions, increasingly used at international and European level. The method consists in the introduction of isolation devices to the interface between superstructure and infrastructure so that seismic force acting on the structure to be absorbed by the isolation system Finally, it presents an example of design calculation for the isolation system according to the new design code in Romania, indicative P100-1: 2013.

***Key words**: earthquake, shock-absorption, seismic isolators*

INTRODUCTION

One of the particularities in the design of structures in Romania is the presence of seismic hazard. Seismic action is often the base action which dimensions the structural elements of buildings.

Starting with the aftermath of the devastating earthquake of 10 November 1940 in our country there have studied and have been gradually introduced mandatory norms for seismic design of buildings in relation to the development knowledge and data in the country and abroad, as well as to the scientific research.

In 1963, 1970, 1981, and most recently in 1991, new norms of anti-seismic design, standards, guidelines and specialty rules for different types of building structures were introduced in practice. The relatively moderate effects of the earthquake of 1977 in our country on buildings designed according to the norms in force in the year1963 and 1970 in comparison to the damaging effects on tall buildings which had been executed without earthquake protection before 1940 are conclusive about the proper concept basis of our norms.

Of course some deficiencies have occurred and will occur in some cases even for buildings after 1940 because progress is achieved through a continuous confrontation with reality by improving calculation and quality control methods.

At the same time, only after 1977 and 1990 there have been obtained, through INCERC network of seismographs, engineering data about the characteristics of strong seismic movements in our country, needed for a modern approach on calculations.

The new regulatory framework for the design and the construction of earthquake resistant buildings SI.100 / 1991 provides measures similar to regulatory norms in countries with high seismicity.

Thus, the seismic protection of buildings aims to limit degradations, failures, and to avoid the falling of structural elements (resistance), of the non-structural (partition walls, other secondary elements), of equipment and installations.

Land seismic oscillation is transmitted to buildings which respond through their own oscillation depending on their dynamic and constructive characteristics.

Constructions withstand either well or improperly the seismic movement particularly depending on their ability to take reactionless side forces induced by an earthquake.

The vertical load bearing capacity (gravitational) was generally well secured as far as the early stages of construction science development. Traditional construction methods in our country provide, considering the experience of living in a seismic area, a certain level of resistance to lateral seismic forces.

The introduction of modern materials (reinforced concrete) at the beginning of our century determined, in our country as well, an excessive reliance on the quality of bearing frame structures, but which in reality could not provide the ability to take over strong seismic (side) forces because anti-seismic calculation methods had not developed enough up to that time.

The structures of brick, metal, wood, reinforced concrete etc. currently used in our country are designed to take over seismic forces.

Earthquakes can cause disastrous problems by:

-blocking main crossroads, due to the collapse of buildings;
-preventing rescue- first aid operations;
-destruction of vital utility networks (water supply, gas, electricity, transport, communications) and the isolation of areas;
-destruction, or lack of functionality of hospital facilities and the occurrence of epidemics;
-the large-scale destruction of residential buildings and the impossibility to provide temporary accommodation for large groups of population in the area.

So far, in our country, the preceding earthquakes have not caused massive disasters of the above-mentioned type.

In the traditional design, in case of a major seismic event, degradation occurs in case of both structural elements, as well as of non-structural ones. This involves carrying out post-earthquake repair and consolidation works. The average recurrence interval considered for relevant earthquakes (MRI = 100 years - According to P100-1 / 2006) reported to the lifetime of a construction makes the traditional design to be more advantageous in terms of initial cost.

Modern methods of design requires for certain phases the use of finite element analysis which allows to obtain safe projects from the point of view of structural strength and durability by: reducing the cost of design and production, material saving, recognizing weaknesses, increasing the quality of the project, optimizing the construction.

MATERIALS AND METHODS

Base isolation method is one of the modern methods for reducing the effects of seismic action on buildings by introducing an isolation system between the land and the structure.

The four fundamental functions of a seismic isolation system are:

1. Transmission of vertical loads;
2. Allowance of displacements on the horizontal plane;
3. Dissipation of substantial quantities of energy.
4. Assurance of self-centring.

These functions can be realized by so called isolators and dampers.

The isolation system consists in seismic isolators (have high rigidity on the vertical and are flexible on the horizontal) and shock-absorbers. In the traditional method, the energy generated by the seismic action is dissipated by controlled degradations in the superstructure elements. In the base isolation method seismic action is taken on the isolation layer and superstructure will remain in elastic behavior area. The idea of the method consists in the fact that for a rigid construction, with its own vibration period corresponding to the maximum amplification area of elastic response spectrum, by introducing the isolation layer, the structure becomes flexible, the natural period of vibration increases significantly, and the effects of the seismic action are reduced.

Base isolation method consists in the introduction of an isolation layer between the land and the structure that isolates the movement of superstructure from the land movement. In the event of a major seismic event no degradations of the structural and non-structural elements are caused, but the method involves a much higher initial cost. Some of the major advantages of the base isolation system is to ensure the continuous operation of their construction and to limit intervention works only to the isolation layer. Base isolation method is effective for constructions with low height and where side displacements are not

prevented (the system works with large side displacements). The idea of the method consists in the fact that for a rigid construction, with its own vibration period corresponding to the maximum amplification area of elastic response spectrum, by introducing the isolation layer, the structure becomes flexible, the natural period of vibration increases significantly, and the effects of the seismic action are reduced. For the isolation system to be effective the ratio between the non-insulated and insulated structure period must be above 3.
The insulating layer consists of seismic insulators and necessarily shock-absorbers. The insulators have a high vertical rigidity to ensure the secure transmission of gravity loads and a low side rigidity to perform the isolation of seismic movement. The ratio between the two rigidity values is between 2500 and 3000.
The main types of insulators are the following:

- natural rubber insulators (NRB);
- Natural rubber insulators with lead core (LRB)
- Synthetic rubber insulators with damping properties (HDRB)
- Devices allowing sliding (SB)

HDBR insulator type consists of several layers of synthetic rubber with cushioning properties, with thickness of 3-10 mm, between which steel plates of 2,5-4 mm are included. These insulators are manufactured with diameters ranging from 500-1500 mm, but the most commonly used diameters are of 600-1200mm. The main parameters of the insulator are S1 factors, S2 respectively. S1 factor is a dimensionless size of the form ratio for a single layer of rubber; for a circular insulator with diameter D and the thickness of the rubber layer tR, the ratio is:

$$S1=D/A*tR.$$

The value of this ratio is between 35 and 40. S2 form factor is the ratio between the insulator diameter D and the total thickness of the rubber layer Tq. The value of this report is about 5. The unitary effort of long-term compression is 10-15N / mm2, and the unitary effort of short-term compression is 15-20N / mm2. The design deformations of these insulators are of 250-300%, and the last deformation of 400%. Due to slow drainage, aging, temperature effects, history of loads, frequency of loading/unloading cycles etc., a reduction of 20% of the insulator parameters occurs. For a side displacement of 300%, an equivalent viscous shock-absorption is obtained of about 20%.

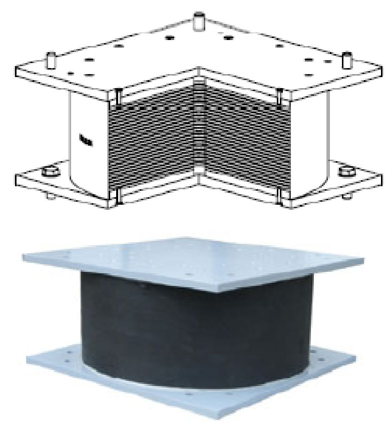

Figure 1. Isolator HDRB

The shock-absorbers are laid to reduce relative movements of the isolation layer, and to stop the movement. The main types of shock-absorbers are: hydraulic shock-absorber (viscous damping type), lead shock-absorbers and steel shock-absorbers (hysteretic damping).
In practice, the principle of Seismic Isolation is that of shifting the fundamental period (= reciprocal value of the frequency) of a building (Figure 2) by the installation of devices with a low horizontal stiffness between foundation and building (Figure 3).

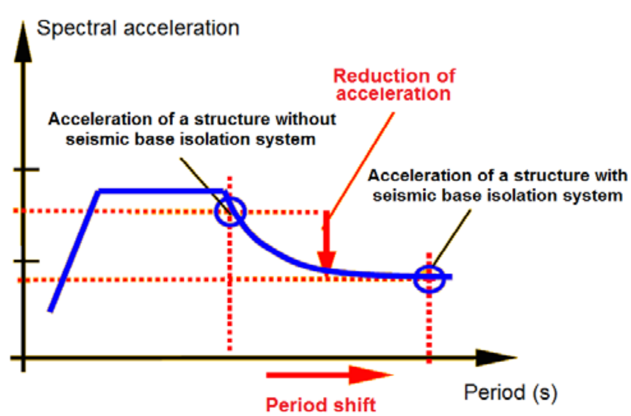

Figure 2. Response spectrum

Figure 3 below shows the effects of seismic movements on both a non-isolated and an isolated structure. Many non-isolated buildings have fundamental periods of 0,2-0,5 sec, especially old buildings with lowest height regime, i.e. the same fall within the typical range of high spectral acceleration (i.e. where the maximum energy content of the response spectrum is concentrated). Thus, the non-isolated buildings undergo resonance that results in dramatic amplification of ground accelerations within the structure as well as large inter-storey displacements. In the case of an isolated building, the fundamental period is shifted into an area with lower spectral accelerations. Resonance effects can be avoided and the building moves smoothly without showing appreciable structural deformations (Dragomir, 2008).

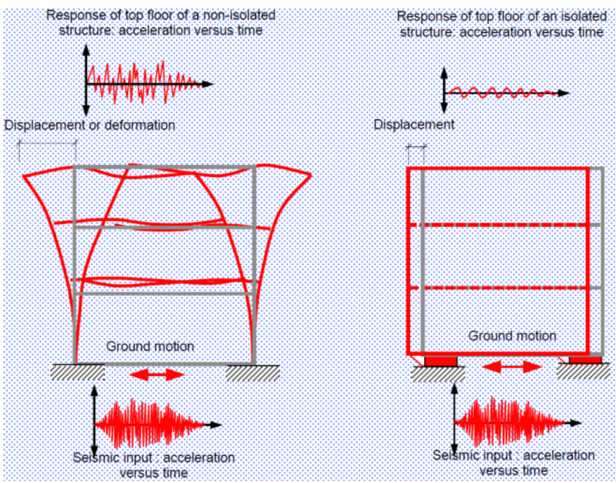

Figure 3. Displacements and deformations of a non-isolated and of an isolated structure

In Figure 4 it can see the general installation of isolation system with High Damping Rubber Bearings.

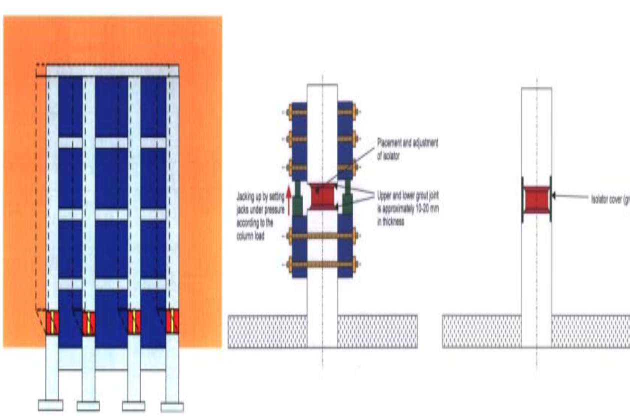

Figure 4. General installation of isolation system

Figure 5. Example of application of base isolation method

We will analyze base isolation method technology for a technological hall with space frames made of reinforced concrete floor (Figure 6).

Hall structure consists of 12 pillars;

Hall area is S=15.00x9.00 m;

Cross-sectional dimensions of the frame are: HframexLframe=4.80x9.00 m.

Under each pillar structure will be placed a seismic isolator.

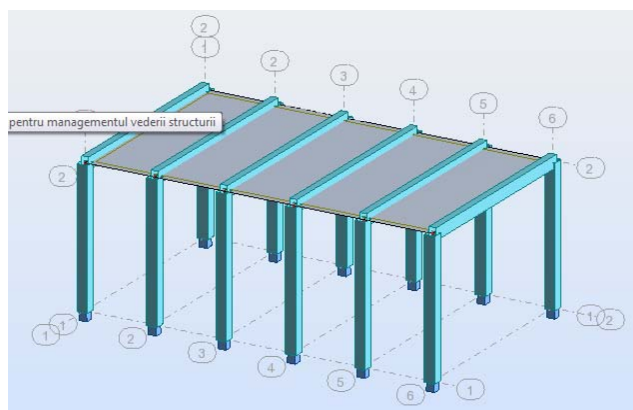

Figure 6. Technological hall

Isolators used will be supplied by MAURER Company, Germany.

The geometrical characteristics of isolators and their number will be established for each body corp.

To set these features was used as the equivalent linear calculation code P100-1/2013.

In determining the number of isolators needed and to determinate the type of isolators we have made the followings calculations:

-Period T = 0,48 s
-Mass M = 74.12 t
-Number of pillars = 12
-Vertical load P =726.86/12 kN=60.57 kN

MAURER Company sells 7 types of seismic isolators:4 types are rubber insert (Table 1) and 3 types are spherical isolators (Table 2). Their features are shown in the tables below:

Table 1. Types of seismic isolators with rubber insert

Maximum upload service (kN)	Type system of seismic isolation	Maximum longitudinal and lateral displacement "s" (service/seismic) (+/- mm)					
		D (mm)	s (mm)	H (mm)	D (mm)	s (mm)	H (mm)
600	V2S	530	35/70	155	530	41/80	175
600	VE2S	530	35/70	185	530	41/80	210
370/450	LRB	280x170/ 280x220		79/90			79/90
600	LRB2E	530	35/55	195	530	41/65	220

Table 2. Types of spherical isolators

Vertical load (kN)	Type system of seismic isolation	Horizontal displacement d (mm)	Dimension Q of the isolator SI (mm)	Seismic isolator height SI (mm)
500	SI	+/- 350	944	90
500	SIP-S	+/- 350	944	194
500	SIP-D	+/- 350	944	184

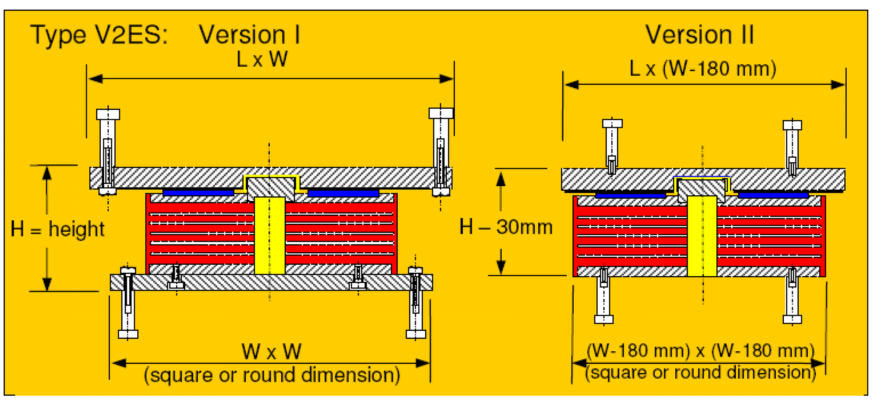

Figure 7. The principle of construction of seismic isolators type LRB-2E

Table 3. Particular type of seismic isolator

Pos.	Load (kN)	No.	Type	Length	Width	Heigh	Rubber height	weight	Price
1	600/1000	12	MLRB	300	400	310	195	300	3500

RESULTS AND DISCUSSIONS

In most cases where the base isolation method is adopted, the layer of isolation is placed at the base of the structure – the case of civil constructions. However, there are some situations when it is more convenient to insulate only a certain amount of mass (in the case of industrial structures with grouped mass).

A very important aspect related to the seismic isolation method is the proper placement of insulators and shock absorbers. They always will be placed so that to avoid torsion.

For the isolation system to be effective the ratio between the non-insulated and insulated structure period must be above 3

By seismic isolation method, due to flexibility of structure, leading to a significant reduction in the level of structure accelerations, the effects of seismic action will be reduced and the amount of materials used will be also reduced. By the reduction of the dynamic amplification factor, the effects of seismic action on the building will be reduced. This reduction represents the idea of seismic isolation method.

A major disadvantage of this method, which limits its use, is that it works with very large side displacements. During the entire duration of the seismic action, the free deformation of the isolation system should be provided. Particular attention must be given to the placement of the isolation, so that to avoid torsion. The seismic isolation method involves a higher initial isolation cost compared to the traditional method, but post-earthquake intervention is more simple, faster and it is limited only to the isolation system level, thus allowing the continuous use of the structure.

CONCLUSIONS

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SECTION 04
WATER RESOURCES MANAGEMENT