SEISMIC REHABILITATION OF BUCHAREST CITY HALL BUILDING THROUGH BASE ISOLATION METHOD

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SUMMARY:
The Bucharest City Hall Building was erected between 1906 and 1911. The brick masonry building with concrete slabs has a simple concrete mat foundation 1.30m height, poured on a sand pillow naturally compacted by flooding it over one year time period. Based on its exposure to four earthquakes 6.7 to 7.4 magnitudes, we deemed this building unsafe. A classical reinforcing solution was devised in 1998 and due to the extensive work employed by this method, all the activities inside the City Hall need to be stopped during the construction work.
The alternative retrofitting solution that will be described was developed on base isolation method. The main advantage resides in the fact that the building does not require its evacuation during the consolidation operation. The principle of the seismic isolation solution is based on decreasing the natural structural frequency of vibration such that a match with the maximum spectral response is avoided.

Keywords: seismic base isolation, spectral response

1. GENERAL BACKGROUND

In general, isolation systems can be very effective in reducing the seismic input to the structure under certain frequency ranges.
The aim of the paper is to show that classical design for seismic rehabilitation is not always very efficient since the ductility demand may be unrealistically excessive. Such is the situation, for instance, in the Romanian earthquakes with focuses in the Vrancea region, were the conjunction of:

- high peak ground accelerations ;
- long predominant periods of the records (about 1.4÷1.6sec. in Bucharest);
- undesirable side effects due to the soft soil conditions, have led to heavy losses and great damages in several catastrophic earthquakes (e.g. the seismic event of March 4 1977 as recorded in Bucharest);

The City Hall Building in Bucharest was erected between the years of 1906 and 1911 on the land next to Cismigiu Park. The architectural design of the 22.000 m^2 total surface area building was done by Petre Antonescu, and the civil engineering work was executed by Elie Radu and Gogu Constantinescu (see Figure 1).

Overall Dimensions:

- Building total length: 89,18m stretching along the Regina Elisabeta Blvd.
- Building side lengths: 65,00m stretching along Elie Radu Str., and 65,00m stretching along Anghel Saligny Str.
- Building overall height: 20,8m, with a peak height of 25,8m over the Festivities Hall.

The building is a brick masonry construction with concrete slabs. Dimensions of the brick walls (see Figure 2):

- The half basement walls have an external and internal thickness of 112cm and 70cm, respectively.
- The ground floor walls have an external and internal thickness of 70cm and 56 cm, respectively.
- The first, second and third floors have external and internal wall thicknesses of 56cm and 42cm, respectively.
- The fourth floor is the attic

Figure 1. Bucharest City Hall Building

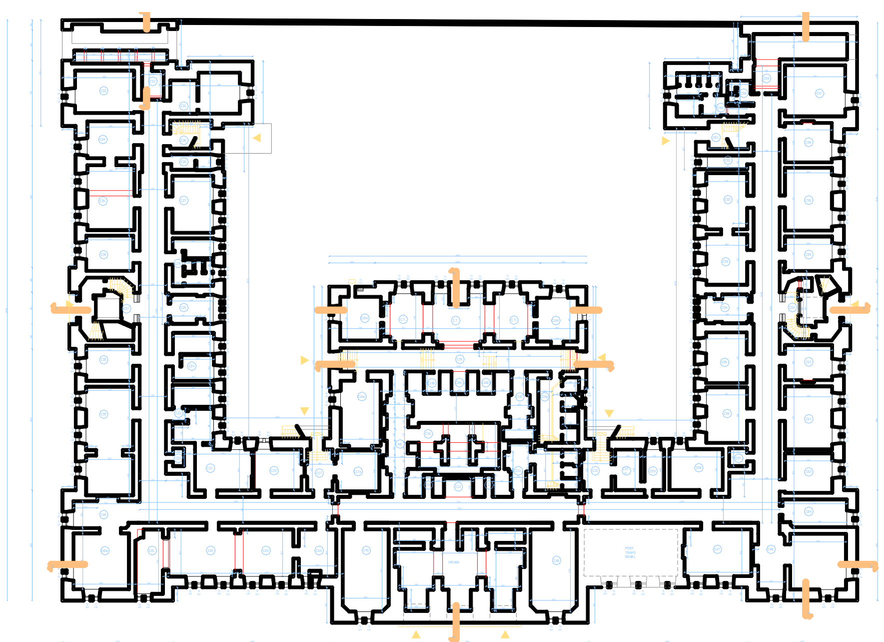

Figure 2. Bucharest City Hall Building Ground Floor

The foundation of the construction is a simple concrete mat foundation with a height h=1.3m, poured on a sand pillow that was naturally compacted by flooding it over one year time period.

This building underwent the following environmental stresses and modifications:

- One earthquake in 10/11/1940, magnitude M=7.4 on Richter scale.
- One floor addition on top of the second floor in 1948.
- One remodelling of the meeting hall on the first floor in 1968.
- One earthquake in 04/03/1977, magnitude M=7.2 on Richter scale.
- One earthquake in 30/08/1986, magnitude M=7.0 on Richter scale.
- One earthquake in 30/05/1990, magnitude M=6.7 on Richter scale.

Based on its exposure to four earthquakes with magnitudes of 6.7 to 7.4 as well as the wear-out of the building through time we deemed this building unsafe and incapable to pass the building codes currently in existence. The building is weakened and highly susceptible to collapse during future severe earthquakes.

A reinforcing solution was devised in1998 and contains the following requirements:
Central section of the building: The current structure will be reinforced by utilizing vertical tubular shape shear walls made of steel reinforced concrete along the entire height of the building. The structure of the first and second floors will also be enhanced by wrapping the walls.
Lateral sections of the building: A similar vertical tubular shear wall made of reinforced concrete will be lining the walls. This procedure will extend from the basement all the way to third floor and used only partially for the fourth floor.
General work:
In concordance with the outlined solutions, the building will be vertically cut in three sections, with the cuts being perpendicular to the Elisabeta Blvd direction. The kerfs of the two cuts will have a width of a 10-15cm, minimum.
The entire land under the building will be reinforced by using a mix of water and sodium-silicon-dioxide ($NaSiO_2$) based cement up to depth of 2.5m.
A generic concrete plate would be poured over the existent one and will have a thickness of 40cm.

In conclusion, due to the extensive work employed by this classic method of reinforcement, all the activities inside the City Hall need to be stopped during the period of the construction work.

2. ALTERNATIVE SOLUTION BASED ON THE BASE ISOLATION METHOD

The consolidation solution that will be described was developed at S.C.PROESCOM SRL and meets all the existing norms and codes. The main advantage of the method resides in the fact that the building does not require its evacuation during the consolidation operation.

The principle of the seismic isolation employed by the PROESCOM solution is based on decreasing the natural frequency of vibration of the building structure such that a match with the maximum amplitude peak found in the spectral response of the building is avoided.

The method of passive isolation of the building base protects the structure by decoupling of the upper level structure from the foundation. The interface between the building upper level structure and the rigid lower structure is comprised by an upper support frame, the isolator members, and a lower support frame (see Figure 3).

Thus, when compared with conventional methods that utilize fixed structures this seismic isolation method minimizes the magnitude of the structural response. This is accomplished by basically decoupling the building from the vibrations of the earth.

The analysis uses a combination of linear and non-linear dynamics and also integrates real time-series data obtained from accelerograms recorded by INCERC during the 1977, 1986, and 1990 earthquakes.

The accelerograms data is deemed relevant to the City Hall Building and was scaled to a maximum acceleration of PGA=0.24g (0.36g for the isolation system).
Furthermore, to reduce the stress and strain levels in the structural elements, an optimization of the stiffness of the isolator members was necessary. The final values obtained for the periods of the isolated building were T= 3.3sec.

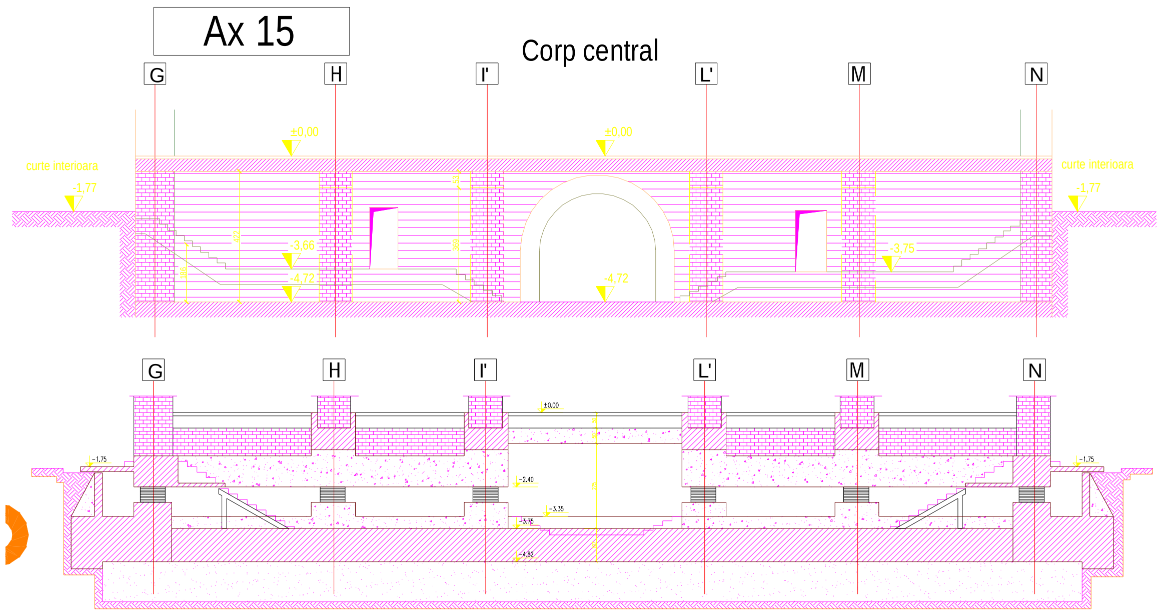

Figure 3. Actual and Proposed Situation – Central Axis

A new element – horizontal reinforced concrete frame has to be install to permit base isolation of the City Hall Building (see Figure 4)

Figure 4. Proposed Horizontal Reinforced Concrete Frame

The initial calculations done for the City Hall Building suggest that 320 isolator bearings of Ø750mm and 375mm height, capable for ±600 mm horizontal displacements and 44 viscous dampers capable for 3000 kN force and ±500 mm stroke are needed. The distributions of the displacements are suggesting a rigid-body type movement. The absolute displacements at the location of the isolation are estimated at 20-25cm and 30-35cm for the longitudinal and orthogonal directions, respectively. Reduction stress factors of 3.5 to 4.0 were obtained through base isolation.

A Prototype Test Plan for adequacy with the design criteria was approved, as follows:

- each isolator shall be inspected during and after each test for sign of defects including lack of rubber to steel bond and laminate placement faults;
- the results of each test shall demonstrate a positive incremental stiffness;
- the results of tests for maximum displacement under various axial loads shall demonstrate no more than 15% difference in effective stiffness between each cycle and the average effective stiffness of each test;
- the bearings shall remain stable during maximum displacement under minimum and maximum axial loads.
- each damper will be horizontally fixtured in a hydraulic tester.
- each damper will be sinusoidally cycled for three complete cycles [Force=(3000 kN-sec/m)V ±15%] at a velocity of 1 m/sec.
- no signs of physical damage, deterioration, permanent deformation, binding or fluid leakage will be allowable.

The seismically isolated option was estimated to produce a saving of 5% in structural cost over the moment-resisting frame option. In addition, the seismically isolated structure will have a considerably enhanced earthquake resistance. Moreover, the repair costs after a major earthquake should be low. Importantly, the seismically isolated structure should be fully operational after a major earthquake.

3. CONCLUSIONS

The retrofitting solution of Bucharest City Hall Building through base isolation method was developed based on PROESCOM SRL patent for inventions, with a previous experience – the successful execution of Victor Slavescu, 2 - 2A Calea Grivitei, Bucharest building consolidation by the same process of base isolation in 2009 (see Figure 5).

Figure 5. Base Isolated Victor Slavescu Building - Calea Grivitei, No.2 -2A, Bucharest

Currently, although from different offers of machinery and seismic equipment presented by the manufacturer, the PROESCOM designer has agreed only to isolation bearings produced by SEP and to seismic dampers produced by Taylor Devices, the City Hall Building officials considered other seismic equipment to be used, which in the designer view fails to comply with the specifications.

It should be noted that similar SEP isolation bearings and Taylor Devices seismic dampers were tested for specific seismic conditions in Romania and have been successfully implemented for base isolation of Victor Slavescu Building - Calea Grivitei, No.2 -2A, Bucharest.

Thus, the beneficiary of technical consulting services dropped from the PROESCOM designer, although the project is protected by a patent, the Building Permit nominated PROESCOM as the designer, and therefore is an ongoing court case on this issue.

Retrofit projects seem to constitute an important proportion of base isolation projects that are under design or are being proposed in Romania.
Results highlighted by the Institute of Earth Physics in Bucharest recordings on Victor SLAVESCU seismic isolated building showed an about 2.8 times seismic response reduction for the 04.10.2011 4.8 Richter magnitude seismic event (see Figure 6).

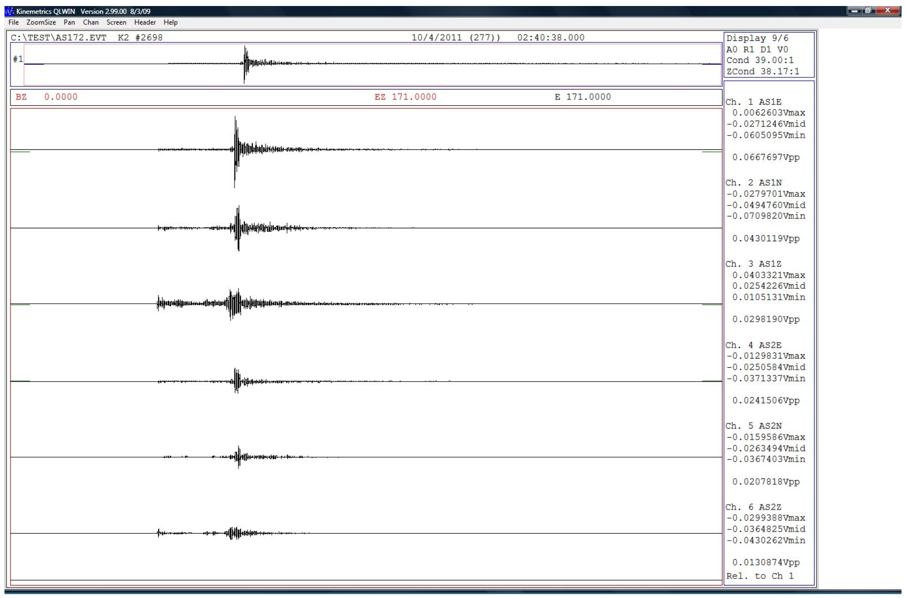

Figure 6. Records for the 04.10.2011 4.8 Richter magnitude seismic event

This has encouraged base isolation method in Romania and especially in Bucharest, although long predominant periods of the records and undesirable side effects due to the soft soil conditions requires special bearing properties.
The Triumph Arch in Bucharest, Romania, base isolation project will be soon under tender process, so that the works should probably start during 2012 fall.

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