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SAFETY STRUCTURAL ASSESSMENT OF REINFORCED CONCRETE BUILDINGS

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Abstract

In all seismic areas, local and state officials and prudent property owner, establish procedures to assess the safety of buildings and other important structures following a main seismic event. Such decisions, in most cases, are based on visual inspections of possible damage to the structure. If the structure appears damaged, it is necessary to further examine and assess as to whether the damage condition of the structure presents an unsafe environment for the occupants of that structure. If available, instrumental measurements of shaking of a building or a nearby ground site are very useful to decision makers. In this sense the paper present a method to assess the building safety of Reinforced Concrete structures using seismic records made by seismic station. Both dynamic analysis and processing/recording of seismic events are made using modern techniques and equipment existent in Reinforced Concrete Laboratory. Mention that seismic equipment for strong motion records belongs National Seismic Network for Construction of National Institute for Research and Development in Construction, Urban Planning and Sustainable Spatial Development.„URBAN-INCERC", and equipment was installed here on the base of cooperation protocol signed by the two institutions. The paper results are conclusive and are discussed both on the charts and analytical results obtained. The activities of this research were conducted under the supervision of PhD. Claudiu-Sorin DRAGOMIR, Lecturer in the Department of Environment and Land Reclamation at the Faculty of Land Reclamation and Environment Engineering Faculty in Bucharest in Bucharest.

Keywords: *seismic action, digital accelerographs, building response, building safety.*

INTRODUCTION

An earthquake is a sudden and powerful, vertical, horizontal or torsion movement of the Earth's crust caused by underground dislocations , volcanic eruptions, tidal forces, meteors colliding the Earth and so on. In case of converging movements of two tectonic plates and especially in the subduction process, the tension created is enormous. When the detension happens earthquakes take place. Earthquakes can intervene in steady state of surface structures of areas, by producing cracks in the bark, followed by collapses, landslides, land subsidence etc.

Earthquakes and landslides may cause negative effects on buildings and construction assemblies which can manifest disastrous by:

- totally or partial destruction (collapse) of vulnerable buildings;
- destruction or damage of parts (structural or non-structural) of buildings;
- destruction/damage of equipment and facilities, of public networks with vital utility (water, gas, electricity, heat, transport, communications);
- fires and explosions in buildings or districts / municipalities;

According to seismic risk assessments, the most vulnerable buildings in this regard are tall buildings of reinforced concrete frame and closing walls or partition walls (masonry) made before 1941 and the old buildings with masonry walls and wooden floors.

MATERIALS AND METHODS

Seismic monitoring of the territory of Romania

Seismic hazard in Romania is due to Vrancea seismic source and several sub-layered surface seismic sources (Banat, Fagaras,

Dobrogea, etc.). Vrancea source is decisive for the seismic hazard for about two thirds of Romania, while surface source contributes more to local seismic hazard.
In Europe, Romania's seismicity can be characterized as medium, but with the particularity that earthquakes with the focus in Vrancea subcrustal source can cause damage over large areas including neighboring countries.
Vrancea earthquakes were noticeable in Europe on surfaces that have reached 2 million square kilometers.

Figure 1. 1977 earthquake

Compared to Vrancea seismic source, other zones of Romania show a reduced activity, more active lately proved to be the Banat zone. In this area it occurred in the last decade relatively strong surface earthquakes (depth outbreaks h≤10 km):
•on July 12, 1991 (magnitude Ms = 5.7 Surface Waves),
•July 18, 1991 (Ms = 5.6) on December 2, 1991 (Ms = 5.6, 5 injured, ~ 1000 buildings collapsed or severely damaged, 4,000 homeless people).
The peak acceleration of ground motion recorded was about 13% of gravitational acceleration.
Other active crustal seismic zones are Fagaras and Dobrogea areas.

Equipment

There are different devices for measuring the characteristics of earthquakes. The most important of these, are the accelerographs and the seismographs. The most popular scales of measuring are Richter Scale and the Mercalli Scale.
A seismograph is a device that measures and records ground movements, in order to analyze seismic movements caused by earthquakes, explosions and other sources. Sometimes earthquakes are caused artificially, for geophysical prospecting. A seismometer is a similar device which is restricted to the measurement of seismographs; recording function being taken over by other devices. Seismographs record a zigzag wave which shows the variable amplitude of the land oscillations under the device.

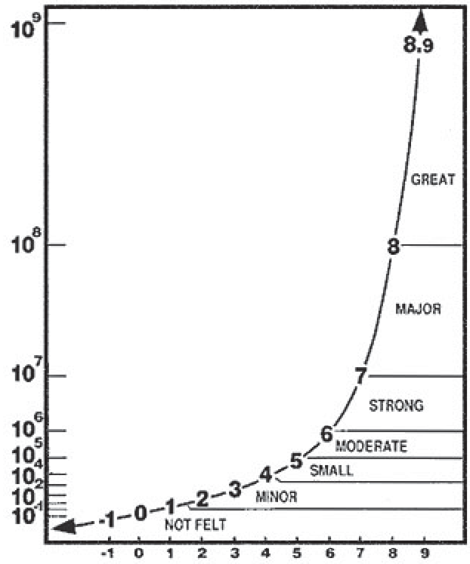

Figure 2. Richter Scale

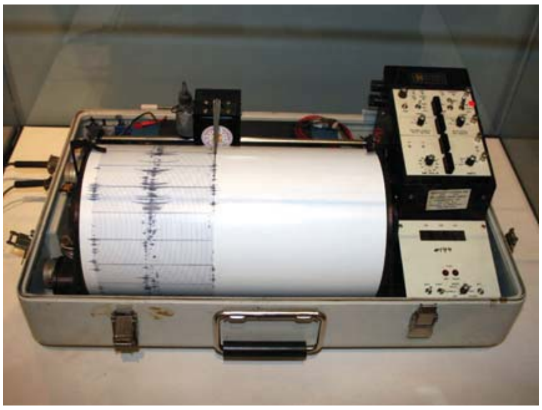

Figure 3. Seismograph

There are also seismographs with an even higher accuracy, which increases recording telluric movements and they can record earthquakes anywhere in the world. The exact timing, location and magnitude can be determined from the data recorded by seismographs.
The equipment presented in Figure 4 is installed in the laboratory of concrete from the Faculty of Land Improvement and Environmental Engineering and it is an integral part of the National Seismic Network

for Construction of the National Institute of Research-Development for Construction, Urban Planning and Sustainable Territorial Development (URBAN-INCERC).

Figure 4.Digital Accelerograph GMS-18 GeoSIG.

Seismic resistance depends on the characteristics conferred by applying some traditional methods of construction or engineering that was improved over time.

Equivalent seismic forces method

Structures vibrations generated by the random movement of the bearing base during an earthquake generates inertial forces. In the current design, modal maximum seismic forces of inertia can be represented by equivalent conventional forces static applied. Linear static calculation process is known as "equivalent lateral forces method" and underpins all regulations for earthquake resistant design of buildings. Conventional seismic forces (computing) depend on the structural and dynamic characteristics of seismic action, represented by the absolute acceleration response spectrums. Equivalent seismic forces are obtained by the independent treatment of each proper mode of vibration k, characterized by its own vibration period Tk, the eigenvector sk and the equivalent modal mass mk. For each proper mode of vibration of the structure with a finite number of dynamic degrees of freedom (DOF) is considered a dynamic system equivalent to a DOF, with the same vibration period and the same base shear force. Maximum modal level seismic forces distribution obtained by modal base shear force distribution according to the vector of vibration acts as lateral static force at structure levels.

RESULTS AND DISCUSSIONS

Seismic analysis of the spatial structure of reinforced concrete using Autodesk Robot

According to the design code, to the indicative P100-1: 2013 and to the method of calculation - the equivalent static forces, shear force corresponding base its fundamental mode for each main horizontal direction considered in the calculation of the building is determined as follows

$$F_b = \gamma_I S_d(T_1) m \lambda$$

Sd (T1) the ordinate of the spectrum design response corresponding to the fundamental period;

T1= fundamental proper period of vibration of the building from the plane containing the horizontal direction considered;

m= total mass of the building calculated as the sum of the masses of level;

λ = correction factor that takes into account the contribution of its fundamental mode Effective modal mass associated with it, whose values are:

- λ = 0.85 if T1 ≤ TC and the building has more than two levels;
- λ = 1.0 in other cases.

Fundamental proper periods T1 and T2 are determined on the basis of some structural dynamic calculation methods.

Figure 5. Reinforced concrete structures analyzed (S_I and S_{II})

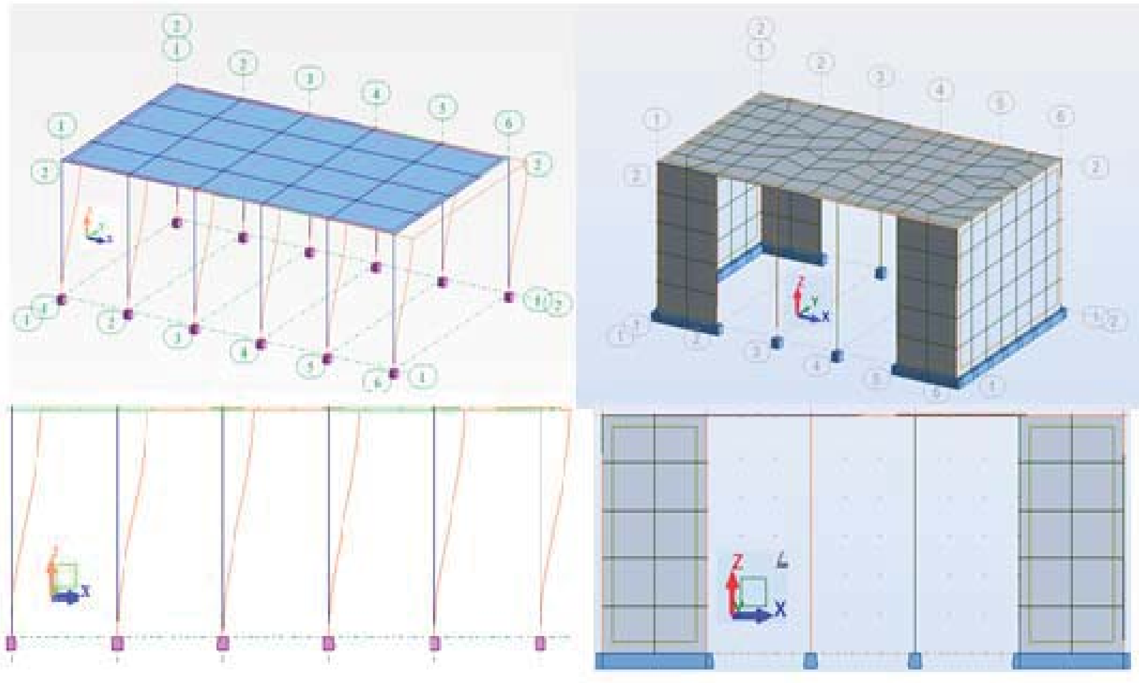

Figure 6. Spatial deformed structures (S_I and S_{II})

The maximum value of displacement at the top of the structure was found in node 51 and has the value:

- For structure SI : d= 5,82 mm;
- For structure SII: d= 0,00089 mm;

Table 1. Oscillation periods corresponding to the values of the 3 fundamental mode

Mode	**Period S_I (s)**	**Period S_{II} (s)**
Mode 1	0,27	0,09
Mode 2	0,23	0,08
Mode 3	0,21	0,07

Checking the maximum displacement under seismic design code, indicative P100-1: 2013 Annex E

q = behavior factor specific to the type of structure

q = 3,5x1,15 = 4,02

Checking the ultimate limit state (ULS) for S I

Checking the status of the ultimate limit is aimed at avoiding loss of human life from the attack of a major earthquake, very rare, that can occur in the life of a building, by preventing the total collapse of the non-structural elements. It seeks both to achieve sufficient safety margin compared to the stage of transfer structural elements.

The verification of movement is based on the relation:

$$d_r^{ULS} = c q d \le d_{r,a}^{ULS}$$

d_r^{ULS}= relative displacement level under seismic action asociated to ULS;

c= factor of amplification movements, which take into account that for T:

$$c = 3 - 2{,}5\frac{T1}{T_c} = 3 - 2{,}5\frac{0.27}{1.00} = 2{,}325$$

$d_{r,a}^{ULS}$ = allowable value of drift movement level, is equal to 0,025h (where h is the height of level).

$$d_{r,a}^{ULS} = 0{,}025h = 0{,}025 \times 6100 = 152{,}5\ mm$$

Checking the ultimate limit state (ULS) for SII

The verification of movement is based on the relation:

$$d_r^{ULS} = c q d \le d_{r,a}^{ULS}$$

d_r^{ULS}= relative displacement level under seismic action asociated to ULS;

c= factor of the amplification movements, which take into account that for T:

$$c = 3 - 2{,}5\frac{T2}{T_c} = 3 - 2{,}5\frac{0.09}{1.00} = 2{,}775$$

$d_{r,a}^{ULS}$ = allowable value of drift movement level, is equal to 0,025h (where h is the height of level).

$$d_{r,a}^{ULS} = 0{,}025h = 0{,}025 \times 6100 = 152{,}5\ mm$$

CONCLUSIONS

The article presents a modern method of structural analysis and validation of the method of structural rehabilitation works using a mix of structural reinforced concrete walls. A global assessment method takes into account the structural use of structural features as well as the period of oscillation of the structure. Investigation of seismic equipment used for the existing structure in reinforced concrete laboratory within the FIFIM. Records obtained are processed with specialized software GeoDAS from GeoSIG, Switzerland. Own periods of the structure is input data in structural analysis carried out with the ROBOT. Finally, by using the process of verification of lateral displacement of structures, the annex E of the code of seismic design of indication P100-1: 2013 is done at the State checking the last ultimate limit (ULS).

The bottom line is that the maximum displacement at the top of the structure does not exceed the permissible value and, at the same time, the proposed solution is validated through the proposed structural.

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