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THE BEHAVIOUR OF REINFORCED CONCRETE BUILDINGS UNDER VRANCEA EARTHQUAKE

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Abstract

From all natural catastrophes the earthquakes are the only unpredictable and the most destructive actions that in a few seconds change the fate of people with their goods. The paper presents a type of structural intervention on reinforced buildings and solutions for determine the dynamic building response. On basis of dynamic response recorded for buildings, a methodology for analysing the structural behaviour of this typology of buildings by adequate software for 3D seismic analysing is presented. For this purpose non-destructive and geodynamic methods were used. All the aforementioned ideas are illustrated through a study case.

***Key words**: seismic action, nondestructive tests, seismic instrumentation, structural analysis*

SEISMIC HAZARD OF VRANCEA AREA

The seismicity of Vrancea is characterized by a source process and some spectral characteristics of this intermediate-depth source in a narrow epicentral and hypocentral region. Thus, according to some studies (Heidbach et al, 2007; Oth et al, 2008; Lungu et al, 2008), for Vrancea source the following characteristics are considered:

- the subduction zone is no longer an active Benioff-Wadati zone, but rather a passively sinking almost detached slab; although the area of high seismicity naturally coincides with high deformation rates this does not necessitate this depth as the actual breakoff zone;
- the seismic events have a maximum instrumentally measured magnitude of 7.7;
- the average amount of seismic moment released per year by Vrancea earthquakes is proportional to the elastic energy release rate, maximum possible magnitude of Mw = 8.0, and it was obtained for 1940, 1977, 1986, 1990 earthquakes;
-indicate large stress release and a difference in attenuation much stronger in the epicentral area and much lower attenuation in the foreland;
- the frequency content of the Vrancea ground motions shows significant differences in source mechanisms, a directivity between events and an asymetric distribution of the ground motion;
- soil condition in Bucharest with long predominant period of ground vibration Tg=1.4-1.6s;

MATERIALS AND METHODS

Behaviour analysis of different types of buildings and the earthquake effect evaluation on them, in addition to a detailed visual inspection of building's state and recording the damage found, in many cases, involves a series of tests and experimental research. Theseare made for both the hidden effect detection and to specify the real characteristics of materials and structural components that have suffered damage.

In Romania seismic protection was provided by P100: 1992 and from 2006, and 2008 respectively, the code P100 was in forced with parts 1:2013 and 3:2008 - which is made in accordance with Eurocode 8. In Romania the

Ordinance no. 20/1994 was promulgated, which includes intervention measures on existing buildings and the Government Emergency Ordinance no. 21/2004 which has institutionalized the National System of Management of Emergency Situations. But now there is no specific legislation to protect university buildings which according to codes above mentioned are included in 2nd Class of importance.

Non-destructive test presented in Fig.2 are used for establish quality of construction materials in new and old buildings. From old buildings is necessary to know the concrete strength to know what strengthening measures to take, and for the new ones to know each execution errors. Measurements were performed with Profometer 5+, Digi Schmidt and Pundit Lab devices (Figure 1), and these measure the rebound index, respectively the propagation speed of the ultrasounds.

a. *Profometer 5+* device   b. *Digi Schmidt* device   5. Pundit Lab device

Figure 1. Equipment used for non-destructive tests

In terms of dynamic, a building can be modelled as an elastic system embedded in the ground through a rigid foundation and the ground can be modelled as elastic half space.
The ground motion is usually a chaotic feature and for this reason the time variation of various kinematical parameters can’t be described in mathematical terms by simple analytical functions. Such phenomena must be modelled by so-called random functions, defined as functions of time for which the values at a time are random variables.
Spectral composition of these oscillations is influenced by the nature of disturbances. It is necessary that the excitation meets a fundamental condition to allow emphasis on the response of the dynamic characteristics of the building. This condition refers to the spectral density of excitation, which should be "broadband", with a constant value on a range of frequencies (pulses) as large as possible.
The use of experimental determinations to identify proper periods, as well as other dynamic characteristics of the constructions, is based on theoretical developments in dynamic structures. Between the period (the term most often used in engineering practice), frequency and pulse exists the simple relationship, as Eq. 1.

$$T = \frac{1}{f} = \frac{2\pi}{\omega}; \quad f = \frac{1}{T} = \frac{\omega}{2\pi}; \quad \omega = \frac{2\pi}{T} = 2\pi f \qquad (1)$$

An important element involved in calculating the building subjected to seismic forces, is the proper vibration period of the building, whose value, determined experimentally, can give an indication of the stiffness and resistance capacity level of these structures to horizontal seismic forces.

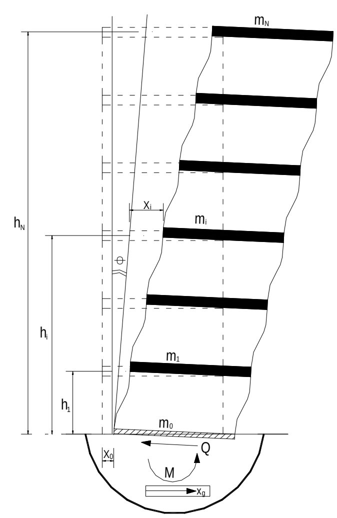

Figure 2. Structure-ground dynamic model

During the earthquake all buildings behave beyond the elastic range, which implies changing of all dynamic characteristics. It is obvious that after the ground motion ends, the structure will remain with modified physical and mechanical characteristics. Thus from the degradation caused by the earthquake, the building' stiffness decreases, the proper periods are increased and the percentage of critical damping increases. So the higher a building is damaged, the higher are the proper periods than their initial ones. But the rigidity and proper period values of the constructions are influenced not only by visible degradations, but also by a series of deformations and invisible cracks accumulated in the building structure, which can be important. Such deformation occurs sometimes later, as observed after the earthquake of 03.04.1977, when to the number of damaged buildings, it was found later, long after the earthquake, an increased occurrence of cracks or appearance of new ones.

Therefore, measuring of proper vibration periods of the buildings in their different situations, namely: after being released to service, before the earthquake, after the effect of the earthquake that caused damages and weakened the structure, or after the strengthening and reinforcement so it allows a determination of the rigidities and therefore very useful assessment of the degree of damage and resistance capacity of buildings.

The equipment presented in Figure 3 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 (Dragomir, 2010).

Figure 3. Digital Accelerograph GMS-18 GeoSIG.

RESULTS AND DISCUSSIONS

For the structural analysis Autodesk Robot Structural Analysis Professional software was used (Dragomir, 2009). As methods of structural analysis method of equivalent static seismic forces and the method of modal analysis with response spectra were used.

In Figure 4 it can be seen structure of the building before and after the structural interventions. Figure 5 presents the space deformations of building under seismic actions graph that contains, in two cases: before and after structural intervention consisting in reinforced concrete walls.

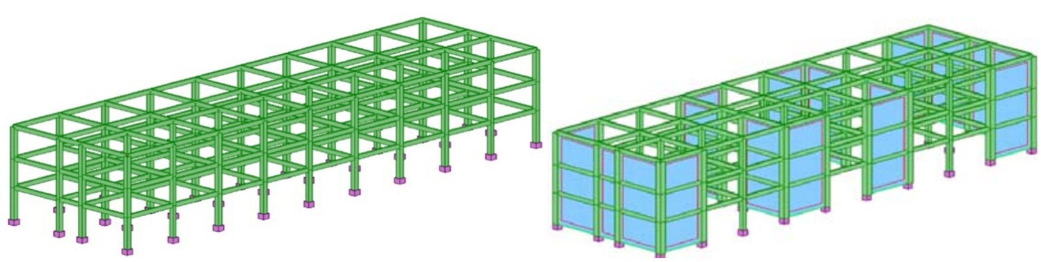

Figure 4. The space structure of the building before and after the structural interventions

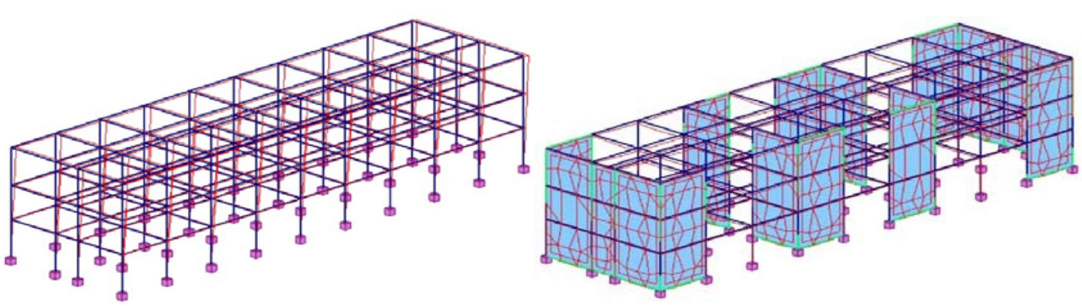

Figure 5. The building deformations before and after structural interventions under seismic action

The results of structural analysis are emphasised in table 1 and 2. It can be seen the increase of the stiffness with 20% after introducing the reinforced concrete walls.

Table 1. Reduction of the seismic risk after the structural interventions

The building	The class of seismic risk		Reduction rate of the seismic risk
	Before seismic intervention	After seismic intervention	
Body C	II (4,77)	III (7.42)	**56%**

Table 2. Increase of the stiffness after the structural interventions

The building	Frequency		Increase of the stiffness
	Before the seismic intervention	After the seismic intervention	
Body C	2,92	3,49	**20%**

CONCLUSIONS

The model for assessment of buildings performances proposes the validation of calculations with a program dedicated to structural analysis using instrumental data processing techniques. The input data are based on non-destructive methods as auscultation, rebar locating, ultrasound velocity, percussion with Schmidt hammer, and the seismic monitoring methods using the GMS 18, GeoSIG equipment.

Applying themodel based on structural analysis and buildings seismic instrumentation can obtain buildings behaviour under seismic actions.

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