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EARTHQUAKES AND THEIR CONSEQUENCES ON BUILDINGDS

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Abstract

In this paper we are going to assess the seismic behavior of the Faculty of Land Reclamation and Environmental Engineering building to future earthquakes, it carries a significant amount of uncertainty. Firstly, most of this is due to the inability to know precisely the characteristics of future earthquakes, and secondly, simplification of the assumptions used to measure the structural response. The increased sensitivity of humankind to natural disasters is not just due to a shift in the way phenomena occur, but rather to anthropogenic factors, which demand even more than before a relevant study of risk factors and the continuous engagement of experts throughout all fields of activity in the reduction of negative effects earthquakes may cause to the individuals, to the infrastructure or to the environmental conditions. The safety of buildings is one of the key efficiency standards for constructions. Expressed in a quality-like approach, these criteria must be enhanced by quantitative factors.

Key words*: irregular buildings, seismic action, seismic instrumentation, structural assessment.*

INTRODUCTION

In Romania there are plenty of buildings that have suffered damage from earthquakes (November 1940 and March 1977). From the experience of these two strong earthquakes, it was concluded that the irregular buildings have the most unfavorable behavior, in some cases, occurring even the collapse.

Over time, Romania has been disturbed by various earthquakes, of smaller or greater severity, with more localized or far-reaching consequences.

Over the past decade, urban growth and construction of taller buildings have increased the level of seismic hazard to cities and counties in various earthquake-prone regions.

For centuries, these seismic events have resulted in a high toll of human casualties and property damage, making Bucharest one of the most threatened among the large population centers in Europe.

The magnitude of seismic risk is significantly higher in the South and East part of the country, while the seismic risk is considerably lower in Transylvania and the Western area of Romania (Dumitru et al., 2013).

Experts concluded that the vast majority of earthquakes in Romania are of tectonic origin, triggered by the discharge of the potential energy stored in some geological structures in the Earth's crust, as well as in the upper part of the mantle (the second layer of the Earth).

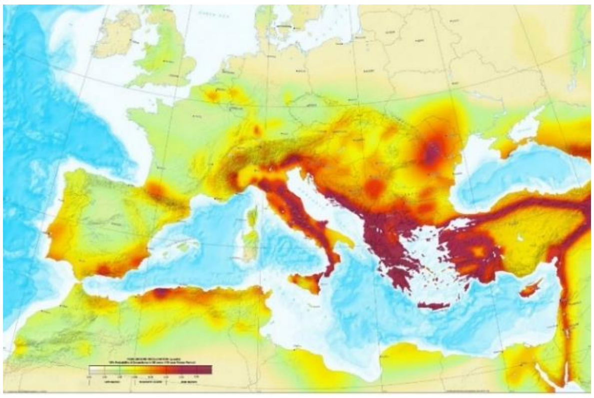


Figure 1. Romania in the seismic setting of Europe (ESC-SESAME Map)

The epicenter areas which decide the magnitude of seismicity of the country: Vrancea, Fagaras-Campulung, Banat, Dobrogea and the continental shelf of the Black Sea, Crisana, Maramures, Transylvanian Plateau and Romanian Plain (Bokelmann and Rodles, 2014).

The Vrancea area of the south-eastern Carpathians is one of the most seismically active regions in Europe and is very well recognized through its powerful intermediate depth earthquakes (Armas et al., 2015).

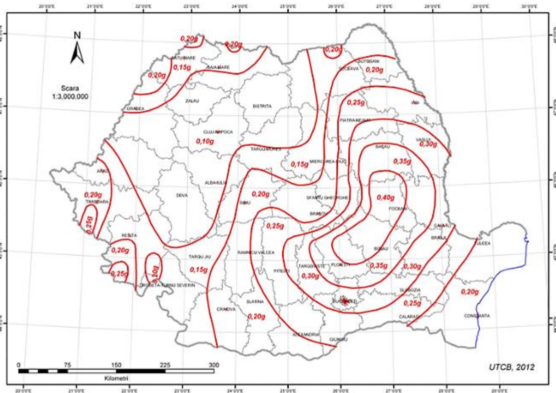


Figure 2. Seismic zoning map from P100-1/2013 (PGA)

MATERIALS AND METHODS

A key point to focus on initially is the seismic performance of structures as a core priority, as they have the greatest consequences on human lives.

Study area

Bucharest begins its development in the 14th century as a market town situated close to the bridges over the Dambovita River at the junction of existing old roads, throughout the field between the forest and the steppe. The face of the city was defined by the disasters that affected it: earthquakes (1701, 1738, 1802, 1838, 1940, 1977), Dambovita's floods, big fires (1802, 1804, 1847), and also by the invasion and influence of foreign troops.

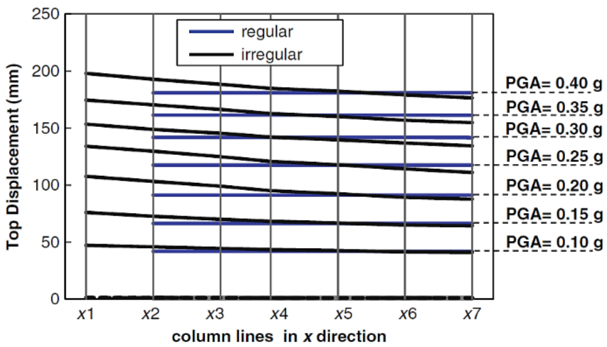


Figure 3. Top story displacement at each column line

Simplicity of a construction implies a continuous and solid enough basic structure to maintain a straight direction, uninterrupted for the seismic loading straight to the foundation surface. Earthquake engineering should focus on creating a structure as regular and uniformly dispersed in a plan such that inertial forces are directly transferred to the foundation in the shortest possible way (Slave, 2011).

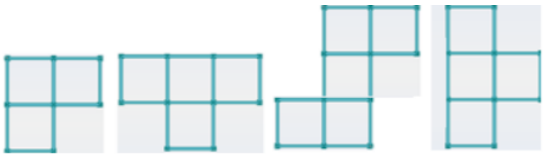


Figure 4. Examples of irregular shapes in plan

Building data

Body A of the Faculty of Land Reclamation and Environmental Engineering, University of Agronomic Sciences and Veterinary Medicine of Bucharest, is the building identified for this analysis. The structure, which was built between 1968 and 1970, has a structure on reinforced concrete frames.
The building selected for evaluation is located in Bucharest. According P100-1/2013, the area is characterized by a peak ground acceleration ag = 0.24g for design and control period of the response spectrum Tc = 1.6sec.

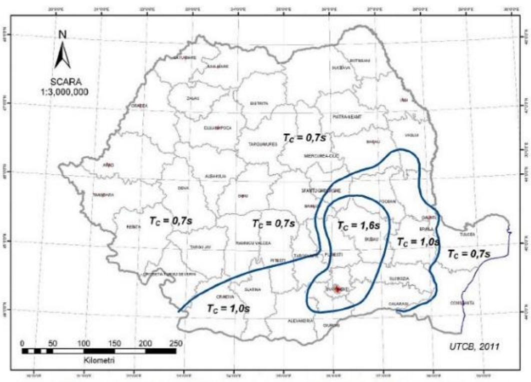


Figure 5. Normalized acceleration spectrum from P100-1/2013

The structure evaluated consists of a ground floor and 4 stories with a gross height of approximately 19 m.
Body A of the Faculty of Land Reclamation and Environmental Engineering building comes into the seismic risk class RsIII -buildings that may have non-significant structural deterioration but significant non-structural deterioration as a consequence of the earthquake design (Slave and Man, 2006).

Figure 6. Building chosen for seismic assessment

The Faculty of Land Reclamation and Environmental Engineering (F.I.F.I.M.) is formed by three buildings divided by seismic joints. Seismic joints are provided between buildings to avoid their collision under seismic action (Dragomir and Dobre, 2019).

The three buildings were designed to meet the requirements for regularity in plan and height. The structure is symmetrical in plan according to the two orthogonal directions. If the construction will generate the phenomenon of subsidence, cracks will affect the body and migrate to the roof.

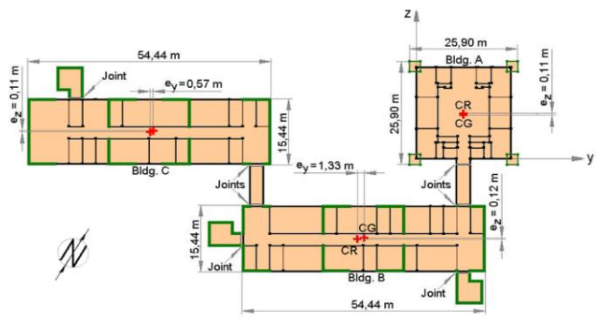


Figure 7. The positions of both centers CG and CR before the structural interventions - the case with seismic joints

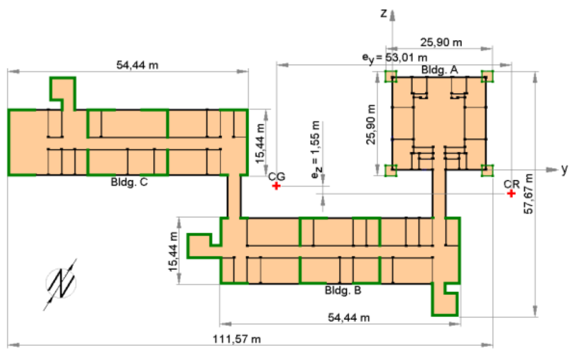


Figure 8. The positions of both centers CG and CR after the structural interventions - the case without seismic joints

Structural characteristics, materials used, foundation and foundation ground

Body A has a reinforced concrete frame structure in two directions, with pillars resting on insulated foundations, at two depth levels: the outer ones at -1.70 m and the inner ones at -0.60 m. The floors are made of reinforced concrete, and hollow brick masonry.

Bodies C and C have a two-way reinforced concrete frame structure with prefabricated reinforced concrete floors. The pillars have reinforced concrete foundations, insulated, and the walls have continuous soles made of concrete. The walls are made of brick masonry.

The connecting bodies have a structure of prefabricated concrete frames. The foundation level is at -2.10, on a layer of clay with an allowable pressure of 175 kPa. Under the pillars there are provided insulated foundations with B75 simple concrete base and B150 reinforced concrete stepped type foundation, the facades are made of 30 cm thick GVP type masonry.

The building's behavior during previous earthquakes

The building withstood three major earthquakes, the first in 1977, the second in 1986, and the third in 1990, all in a seismic zone of degree VIII.

The 1977 earthquake caused isolated structural damage to the buildings on the Agronomic University Campus as well as significant damage to the structural elements.

The 1986 caused a reactivation of the 1977 effects, as well as causing new damages to some structural components.

The 1990 earthquake caused visible damage to both structural and non-structural components of almost all structures, though finishing operations have been conducted in the meantime.

Seismic instrumentation of the buildings. Case study – building F.I.F.I.M. Bucharest

All 3 corps of the building F.I.F.I.M.:

- Structural resistance made of reinforced concrete.
- Designed during the seventies, under P13-70;
- H = 20,33 m;

On March 4, 1977 damages were mainly made to the partition walls.

$$\begin{cases} k_1 = m\left(\dfrac{2\pi}{T_1}\right) \\ k_2 = m\left(\dfrac{2\pi}{T_2}\right) \end{cases} \Rightarrow \frac{k_2}{k_1}x100 = \left(\frac{T_1}{T_2}\right)^2 x100$$

Validation of the results achieved by modeling using structure calculation software ROBOT Millennium

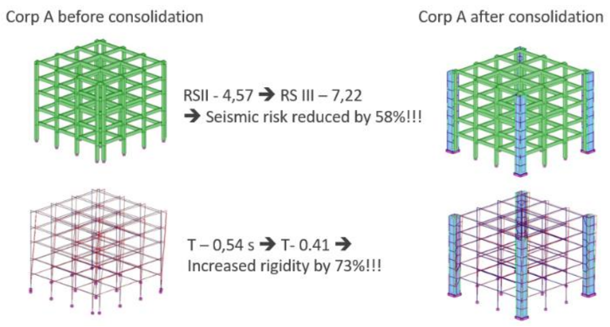


Figure 9. Spatial deformation of corp A after an earthquake, before and after consolidation

The issue of irregularity of the buildings is resolved in compliance with Eurocode 8 and Seismic Project Code P100-1: 2013, by studying the relationship between the centre of rotation (CR) and the centre of gravity (CG) (Dragomir et al., 2016).
Eccentricity can provide a global picture of the torque applied to the structure in question, as well as the structural interventions required to reduce the effects. The building's modelling and structural analysis were performed with the ROBOT Autodesk program, and the dynamic characteristics determined by temporary seismic instrumentation of the structure using GMS-18 equipment and GeoDAS software have been used as input to match the structural model.

Seismic Risk Assessment of RC buildings

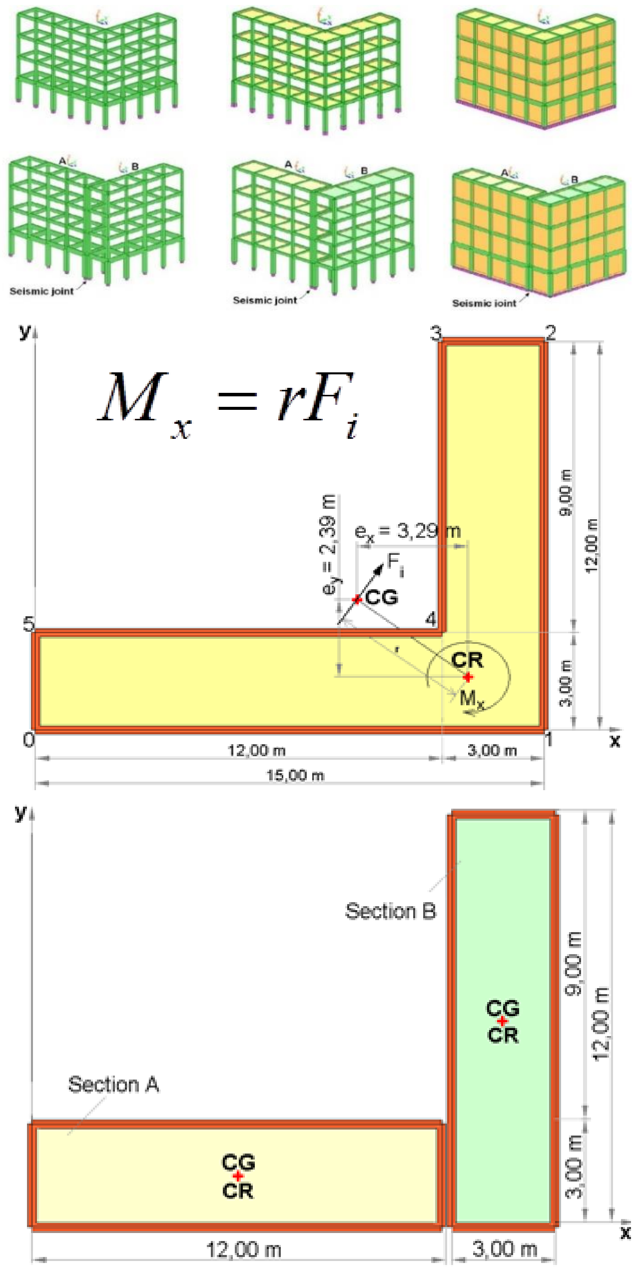


Figure 10. Space structure of L shaped-plan before and after sectioning, in different structural typologies

Monitoring the structures by seismic instrumentation

Monitoring:

- Creating maps representing the area of seismic activity
- Identifying structural characteristics
- Identifying restore and consolidation requirements
- The efficiency of previous intervention measures.

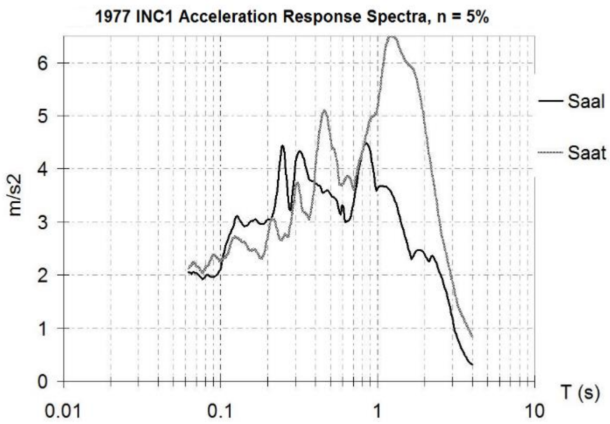


Figure 11. On March 4, 1977 – first recorded data of engineering concern to INCERC

Minimal instrumentation:

- 1 sensor in free-field
- 1 sensor to ground floor
- 1 sensor on the ceiling of the last floor

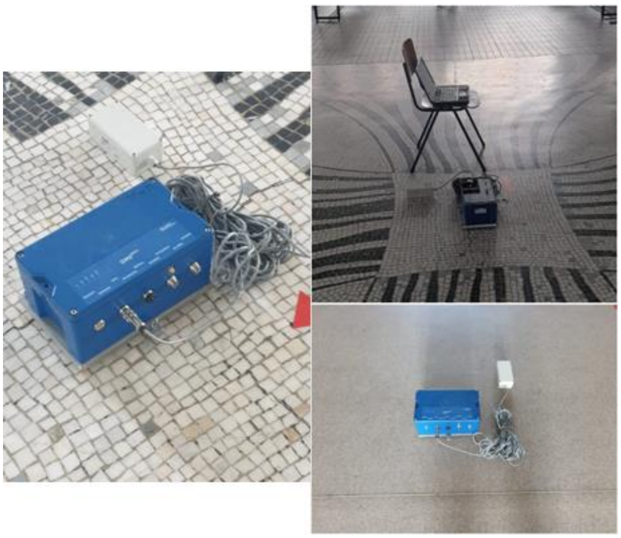


Figure 12. Seismic instrumentation used for the case study building – building F.I.F.I.M.

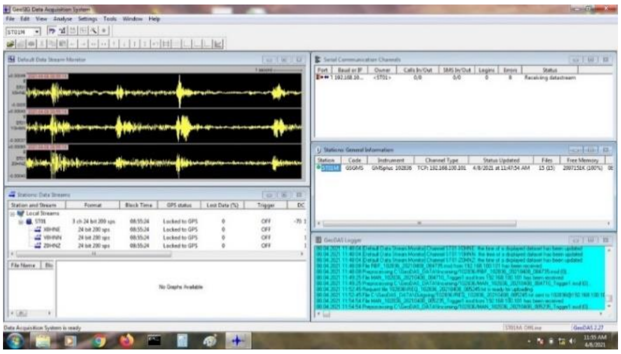
RESULTS AND DISCUSSIONS

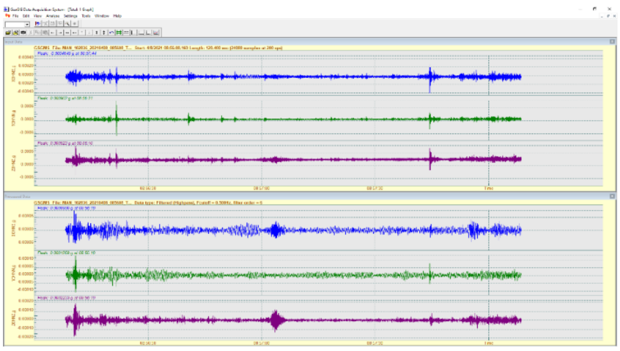
The results of this study reveal that geometry plays an important role in seismic engineering, and that there are situations when remodeling a building can be effective, especially when using advanced technologies available on the European market.
According to the structural analysis, a 73% improvement in rigidity was achieved by consolidation solutions with marginal pillars (Dragomir et al., 2019).

What is indicated by the structural analysis is also confirmed by the seismic monitoring results.
Reduced oscillation periods results in increased rigidity.

Date	Execution type	Oscillation direction	
		Transversal	Longitudinal
3.12.1986	microseisms	0.62	0.57
19.11.1990	microseisms	0.53	0.43
11.10.1996	microseisms	0.50	0.44
11.10.1996	Explosion-maximum excitation	0.57	0.50
11.10.1996	Explosion-free vibration	0.53	0.44
13.02.1998	microseisms	0.42 – 0.44	0.40 – 0.42
21.12.2009	microseisms	0.35	0.42
02.03.2012	microseisms	0.38	0.42 – 0.44
05.04.2021	microseisms	0.40	0.42

Figure 13. Evolution in time (1986-2021) of specifics periods to corp A of the building





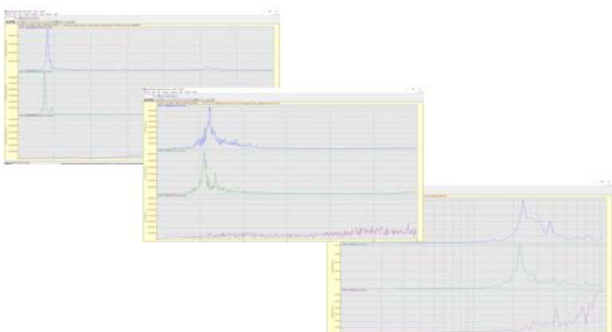


Figure 14. Own periods of body A identified by the processing and analysis of the registration from April 5, 2021

CONCLUSIONS

In-situ instrumental data contribute to a correct understanding of the importance and of the influence of various factors on the structural dynamic response, as well as their correlation with interest objectives for the building owners/beneficiary.

In this regard, the determination of the dynamic characteristics of building structures is one of the most important aspects of structural health monitoring. The results are conclusive and are discussed both on the charts and analytical results obtained.

By using the concept of performance assessment, it can predict how certain structures that have experienced earthquakes in the last century will respond to future earthquakes (Dragomir et al., 2016).

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SECTION 03
CADASTRE