
ASPECTS ON THE MEASURES APPLIED AT NATIONAL LEVEL FOR THE SAFETY OF VULNERABLE BUILDING STOCK IN BUCHAREST MUNICIPALITY

Ana-Maria PÎRVĂNUȘ (GEORGESCU)¹

¹ PhD Student, Technical University of Civil Engineering, 122-124 Lacul Tei Boulevard, Bucharest, Romania

e-mail: ana_maria_pirvanus@yahoo.com

ABSTRACT

The seismic vulnerability assessment of buildings is an essential tool to describe the seismic safety of structures to be used in disaster preparedness, loss estimation, planning and prioritizing investments for building retrofitting. The seismic vulnerability depends mainly on human action, the way buildings were protected at seismic action and on their economic value. The vulnerability also depends on the degree of decay and the decrease in resistance of the structures, resulting from repeated exposure to various environmental factors. The overall trend is to increase the vulnerability over time, this being associated both with the increase in the market value of upgraded buildings which may be seriously damaged and also with the decrease of their structural resistance. The article provides an overview of the building stock in terms of seismic risk and a summary of the measures taken by the public authorities to assess seismic vulnerability and seismic risk mitigation to existing buildings in Bucharest. A synthesis of the actions focused on the development of strategies, policies and plans at national level to streamline seismic risk reduction efforts is also presented.

Keywords: seismic vulnerability, technical assessment, seismic risk classes

REZUMAT

Evaluarea vulnerabilității seismice a construcțiilor este un instrument esențial în vederea descrierii siguranței seismice a structurilor, fiind utilă în pregătirea pentru dezastre, estimarea pierderilor, planificarea și prioritizarea investițiilor pentru consolidarea clădirilor. Vulnerabilitatea seismică depinde în principal de acțiunea omului, de modul cum au fost protejate la acțiunea seismică obiectivele construite și de valoarea economică a acestora. De asemenea, vulnerabilitatea depinde de gradul de uzură și de scăderea rezistenței structurilor, ca urmare a expunerii repetate la diferiți factori de mediu. Tendința generală este ca vulnerabilitatea să crească în timp, fapt asociat uneori creșterii valorii de piață a clădirilor ce pot fi distruse, cât și din cauza diminuării rezistenței acestora. În cadrul articolului este realizată o prezentare generală a situației fondului construit din punct de vedere al riscului seismic și o sinteză a măsurilor întreprinse de autoritățile publice pentru evaluarea vulnerabilității seismice și reducerea riscului seismic la clădirile existente din municipiul București. De asemenea este prezentată o sinteză a acțiunilor preconizate pentru dezvoltarea strategiilor, politicilor și planurilor la nivel național în vederea eficientizării eforturilor de reducere a riscului seismic.

Cuvinte cheie: vulnerabilitate seismică, expertiză tehnică, clase de risc seismic

1. INTRODUCTION

Romania is considered one of the countries with the most active seismicity in Europe, the seismic hazard in the south and east of the country being associated with the Vrancea intermediate-depth seismic source [1].

Based on the evaluations carried out within the RO-RISK project, it results that approx. 75% of the population (of which 65% of the urban population) and 45% of vital networks are exposed to seismic risk. Moreover, 60–75% of Romania's fixed assets, which contribute to 70–80% of the country's

gross domestic product (GDP), are located in seismic areas [2], [3].

The major earthquakes with magnitude $M_w > 7$ from the Vrancea subcrustal seismic source, that affected the Romanian territory, have occurred on October 26, 1802 ($M_w = 7.9$), November 26, 1829 ($M_w = 7.3$), January 23 1838 ($M_w = 7.5$), October 6, 1908 ($M_w = 7.1$, $h = 125$ km), November 10, 1940 ($M_w = 7.7$, $h = 150$ km), March 4, 1977 ($M_w = 7.4$, $h = 94$ km), 30 August 1986 ($M_w = 7.1$, $h = 131$ km). Regarding the estimated losses after the 1977 Vrancea earthquake, statistical data related to the impact of the earthquake on elements exposed to seismic risk were reported: 1,570 deaths, 11,300 casualties and economic losses of 2 billion USD, of which 50% generated by the construction sector [4], [5], [6].

Moreover, Bucharest is considered one of the 10 most vulnerable cities to earthquakes in the world, being called "the European earthquake capital", in the article "Risky cities: red equals danger in Bucharest, Europe's earthquake capital" published by the daily newspaper "The Guardian" (online edition of March 25, 2014), due to its relatively close location to the Vrancea seismic source, the high population density, the age of the existing building stock and infrastructure, as well as due to the relatively low level of education of the population for seismic risk reduction.

According to statistics at European and international scale [7], Romania is among the top 10 countries in the world in terms of earthquake exposure by built area.

The experience of the March 4, 1977 earthquake showed that the most vulnerable category of construction was that of relatively tall buildings (8-12 floors), built before World War II. The main causes of their high vulnerability are: the poor quality of construction materials, the cumulative negative effects of previous earthquakes, corrosion, fatigue caused by urban traffic, interventions with adverse effects to the structure, made by the owners or occupants of the buildings. On the other hand, a phenomenon of quasi-resonance related to the ratio between the predominant periods of the

ground motion in case of strong earthquakes and the eigenperiods of the buildings may have had influence. The reported data on building damage after the 1977 earthquake indicates that, of the total of 32 collapsed buildings, 28 belonged to the latest category, which clearly highlighted its high vulnerability [5], [8].

The earthquake of March 4, 1977, beyond its disastrous effects, led to the development of earthquake engineering in Romania [9], and of its impact, as post-disaster actions and policies; it was a benchmark for the continuous improvement of seismic risk measures [10].

For seismic risk assessment, it is necessary to know in advance its components, shown in Figure 1.

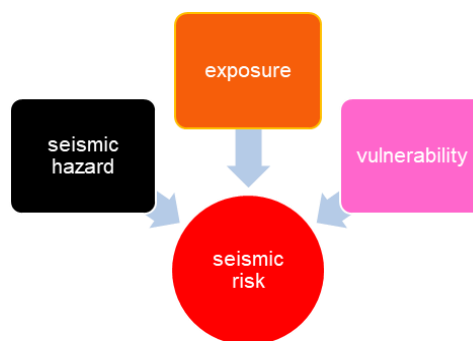


Fig. 1. Seismic risk components

Seismic risk is quantified by the high number of expected human casualties, damage to property, economic losses and disruption of economic activities. In term of its components, seismic risk is the "product" between hazard and vulnerability of elements exposed to risk, taking also into account their exposure [11].

Risk analyses recognize the impossibility of the deterministic prediction of: seismic events used within seismic scenarios for calculations, vulnerability of elements exposed to risk and chain effects that occur as a consequence of earthquake damage.

Assessing the seismic vulnerability of existing buildings allows the estimation of losses caused by an expected seismic event, being of national interest to public authorities both in preventing a potential disaster by intervening on risky buildings and in preparing to manage an expected hazard level.

Whereas parts of Europe are exposed to seismic risk, there are recommendations for an integrated approach of interventions works on buildings, related to structural retrofitting and energy renovation. In this respect, the provisions of the EU Directive 2018/844 require that Member States address issues related to seismic risk and fire safety affecting the life of the buildings.

2. LEGAL FRAMEWORK ADDRESSING SEISMIC RISK ISSUES

Seismic risk mitigation at national level is subject to a legal and technical regulatory framework that aims to establish measures for reducing the vulnerability of the building stock by imposing requirements for design and execution of new constructions, as well as for retrofitting the existing ones.

In this context, in 1994 came into force Government Ordinance No. 20, on measures to reduce the seismic risk of existing buildings. This document regulates the legal framework on the identification of buildings to be retrofitted and the stages of retrofitting works. Over time, several amendments and additions of the ordinance were made, followed in 2001 by the approval of the methodological application norms, by the Government Decision No. 1364/2001.

At the same time, in 2001, the first regulatory act was approved, which establishes provisions regarding the actions needed to be taken for the identification of areas exposed to natural risks, including earthquakes, i.e. Law no. 575/2001 regarding the approval of the National Territory Planning Plan - Section V - Natural risk areas. According to this law, in the geographically delimited natural risk areas and thus declared according to the law, specific measures on the prevention and risk mitigation, construction and land use were set in order to be included in urban and spatial planning plans, framework for disaster preparation and response management.

In Romania, there is a comprehensive regulatory framework on seismic safety, regularly updated and implemented in the last

five decades for both new and existing buildings [12]:

- Provisional instructions for preventing earthquakes damage to buildings and for the restoration of degraded ones, approved by Decision No. 84351/1941;

- STAS 2923-58 (not enforced): General design requirements in seismic regions. Seismic loads;

- Conditional norm for the design of civil and industrial buildings in seismic regions, indicative P13-63;

- Normative for the design of civil and industrial buildings in seismic areas, indicative P13-70;

- Normative for the aseismic design of social-cultural, agro-zootechnical and industrial buildings, indicative P100-78, P100-81;

- Normative for anti-seismic design of housing constructions, social/cultural, agro-zootechnical and industrial, indicative P100-91, P100-92;

- Seismic design code, Part I - Design provisions for buildings, indicative P100-1/2006, P 100-1/2013, with own zoning maps, amended and supplemented in 2019 to standardize the application at national level for ensuring the safety of constructions to seismic action, in accordance with the fundamental requirements of the code;

- Seismic design code - Part III. Provisions for the seismic assessment of existing buildings, indicative P100-3/2008, revised in 2019 by amending a series of provisions on the stages, operations, activities and verifications for an unified and uniform adoption of the framework assessment (technical assessment) of existing buildings to seismic action, in order to facilitate the proper application in the seismic assessment process.

Regarding the legal framework on the seismic risk management, it should be noted the actions to reduce the impact of natural disasters in line with the current strategic approaches implemented at international level, set by the Sendai Framework for Disaster Risk Reduction 2015-2030.

In order to adopt and implement the strategic objectives and priorities of Sendai

Framework for Disaster Risk Reduction 2015-2030 [17], the National Platform for Disaster Risk Reduction was established, according to the provisions of Government Decision No. 768/2016. The national platform contributes to improve the decision-making process regarding the policies and action plans for disaster prevention and the streamlining of emergency management through the involvement of public authorities, specialists and civil society for a more effective disaster management and increased citizen resilience. In addition, the framework of risk management is set out by the Government Decision No. 557/2016, where specific provisions related to the areas of action for preventing, preparing, responding and recovery/rehabilitation are defined for responsible authorities and support functions for each managed type of risk.

Currently, at public authorities' level, a series of steps were taken for optimizing the legal framework by revising the technical regulations in the field of seismic risk reduction, legislative proposals and public policies. In the same context, the efforts are focused on the correlation with European/international requirements and objectives, in order to provide unitary approaches in line with the necessary actions to reduce disaster risks.

Regarding the seismic risk management measures related to the post-event investigation, it can be mentioned the "Methodology for the emergency investigation of post-earthquake safety of buildings and for establishing solutions - intervention framework", indicative ME 003/2007, which sets the organization and carrying out of technical activities aimed to ensure the safe use of buildings after an earthquake. This methodology describes the procedure for assessing the technical condition of buildings affected by earthquake in order to decide on the conditions of their continued use or decommissioning (evacuation, demolition) and to take measures for the temporary safety of buildings [13].

A set of actions and measures for the prevention, protection and immediate

intervention, recovery and rehabilitation necessary to limit the effects of earthquakes/landslides, as well as the attributions of the structures involved in the management of emergencies, were adopted by the Joint Order of the Minister of Transport, Construction and Tourism No. 1995/2005 and of the Minister of Administration and Interior No. 1160/2006.

3. OVERVIEW OF THE SEISMIC VULNERABILITY IN BUCHAREST AND MEASURES TO PRIORITIZE ACTIONS FOR SEISMIC RISK REDUCTION

The seismic vulnerability of buildings is defined as the sum of the expected damages induced by a certain intensity of the seismic motion (United Nations Development Program, 2004). This is a measure of the destructive effects produced by strong seismic actions on exposed elements or built systems.

The seismic risk of buildings can be expressed depending on the specific parameters of the source (focal mechanism), the ground motion at the site (local conditions) and the structural characteristics of the exposed elements (conditions for the seismic protection of structures).

Various terms correlated to the vulnerability are used in the literature: degradation or damage, average degree of damage, damage index, vulnerability classes, damage probability matrix, vulnerability index, vulnerability curves, fragility curves, etc., as shown in Figure 2.



Fig. 2. Vulnerability terms

Generally, it is considered that the following key elements have to be considered for the seismic vulnerability assessment of buildings, such as: deformation capacity and strength of structural elements, properties of building materials, structural configuration, foundation, soil conditions, soil-structure interaction, importance class of the building, age of construction, safety of the non-structural elements and local seismic hazard.

From the point of view of seismic vulnerability, the existing building stock, as well as the recently-built one, has to be assessed according to several considerations: construction period of the building, applied design and construction codes, architectural, structural and functional building typologies, height, geological and geotechnical parameters of the soils at the building site, distribution of the population per built typologies.

Vulnerable buildings from the existing building stock in Romania were classified into two main categories [14]:

a) Tall or medium-height buildings, built before 1945 - these buildings are characterized by uniqueness, the architectural and structural systems differ from one building to another, not being designed with seismic provisions;

b) Tall or medium-height buildings, built after 1945, but before the March 4, 1977 earthquake.

During the 1977 Vrancea earthquake, 32 buildings collapsed in the central area of Bucharest, of which 28 tall buildings that were built before the World War II, when no seismic design rules for buildings were applied [5]. The distribution of tall buildings built before 1945 in the center of Bucharest covers a circular area delimited by Piața Romană and Piața Unirii (N-S) and Cișmigiu-Vasile Lascăr-Calea Moșilor (E-V). In this area there are about 400 tall buildings with more than 4 stories, erected before 1945, one third of them being 8 story-high [15].

According to the data resulting from the last census conducted in Romania in 2011 (National Institute of Statistics, <http://www.insse.ro>), the building stock in Bucharest Municipality consists of 113,863

buildings, with 804,287 housing units and 1,883,425 people living in them.

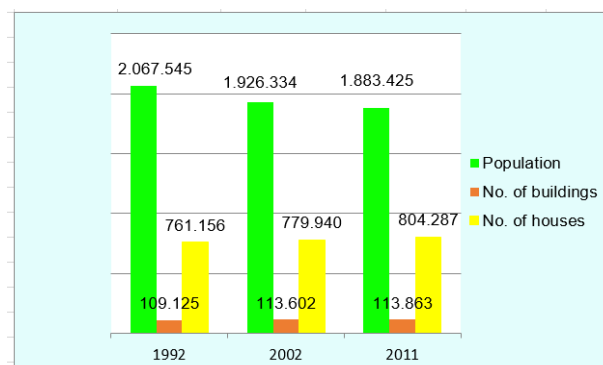


Fig. 3. Evolution of the population and buildings in Bucharest

From the figure above it can be observed that although the number of the population is in a continuous decrease, the number of buildings and thus of the houses is in a permanent increase. Taking into account that seismic risk reduction measures aim to reduce the vulnerability of the existing building stock, these measures must be based on a solid and comprehensive knowledge of the vulnerability.

After 1990, public authorities started a program to assess the seismic resistance of vulnerable buildings, by promoting the concept of “building technical assessment report”. Buildings classified in seismic risk class I needed to be urgently retrofitted.

Thereby, the technical assessment of potentially vulnerable buildings was financed, intervention priorities were identified and work on seismically vulnerable buildings was initiated.

Usually, buildings’ vulnerability to seismic actions is evaluated by a technical assessment, developed by a technical expert specifically certified by the Ministry of Public Works, Development and Administration for mechanical strength and stability requirements, according to the building quality assurance system.

The seismic assessment report has the purpose to establish the susceptibility of damage to severe seismic actions, the need for intervention works and the type and scope of intervention works for reducing the seismic vulnerability of buildings.

The assessment of the seismic risk for a certain building is done by categorizing it in one of the four risk classes defined by the technical regulation P100-3/2019 [16].

As an overview of the Bucharest Municipality, Figure 4 presents the classification of technically assessed residential buildings in seismic risk classes, by districts, according to the List published by the Municipal Administration for the Retrofitting of Buildings at Seismic Risk, after the last update on 25.09.2020 (<https://amccrs-pmb.ro/liste-imobile>).

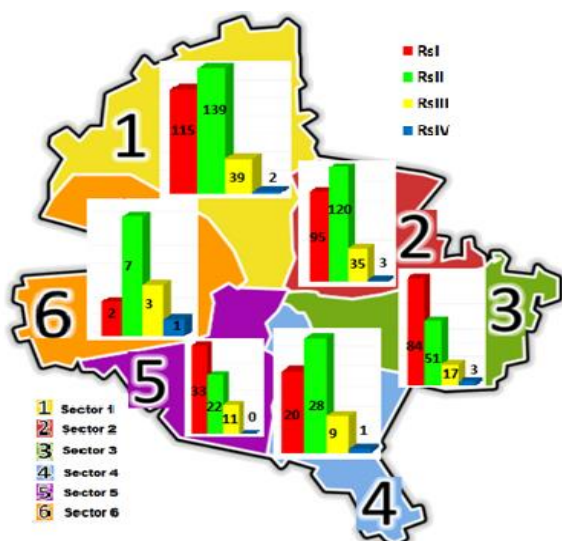


Fig. 4. Situation in Bucharest of residential buildings classified in seismic risk classes

Until 2020, in Bucharest Municipality, 840 buildings with various numbers of stories were technically assessed and classified in seismic risk classes, 35% of them being located in District (Sector) 1.

Based on a more detailed analysis, as illustrated in Figure 5, it can be noticed that the largest number of buildings included in the 1st seismic risk class, called “RsI” - which includes buildings susceptible of total or partial collapse under the action of the design earthquake corresponding to the ultimate limit state - are located in Districts 1 and 2 of Bucharest (about 60% of the total of 349 buildings: the majority was built in the period between the two world wars and their structure was subjected to major earthquakes, without taking proper retrofitting measures afterwards).

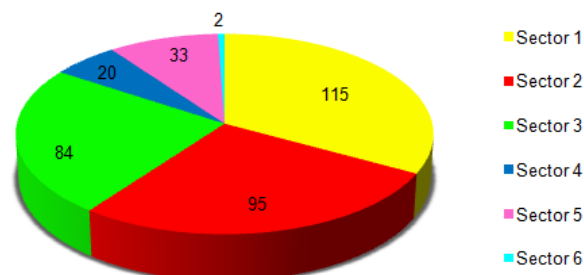


Fig. 5. Situation of buildings in Bucharest classified in the 1st seismic risk class

To date, in Bucharest, 97 buildings, totaling 1131 apartments, have been retrofitted, which represents approximately 28% of the number of buildings technically assessed and classified in the 1st seismic risk class, as shown in Figures 6 and 7.

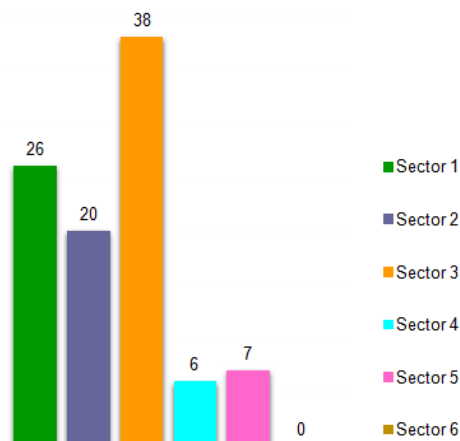


Fig. 6. The situation of buildings retrofitted until 2020 in Bucharest

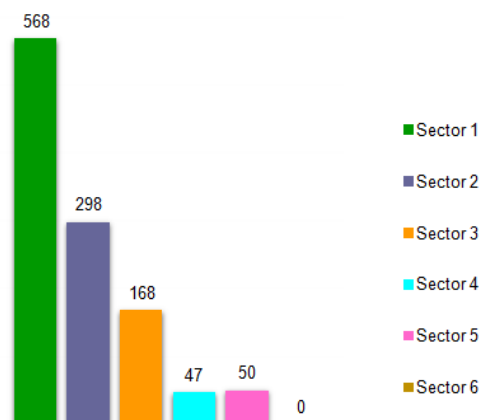


Fig. 7. Number of apartments in buildings retrofitted until 2020 in Bucharest

Taking into account the statistics of costs for carrying out the retrofitting works, several estimations of the necessary costs to reduce the seismic vulnerability of residential

buildings classified in the 1st seismic risk class with no previous retrofitting works were carried out. Thus, it can be estimated that, for the reinforcement works of 252 buildings, an amount of millions Euro is necessary. In this context, multiple sources and funding mechanisms are essential to make significant progress in reducing the seismic risk.

At the same time, it is necessary to conduct a large scale building stock inventory, for better targeting and prioritization of investments in seismic risk reduction measures and for an increased awareness of the authorities regarding building safety, as well as for providing funds to meet the needs that are essential for this approach.

4. CONCLUSIONS

The mitigation of the seismic risk of existing buildings and the increase of citizens' safety is a matter of national interest and public utility. Therefore, ensuring the protection of life and physical integrity of the population, maintaining activities and services essential to social and economic life, and limiting the material losses are important objectives for the seismic assessment of existing buildings and for setting the appropriate intervention strategy, in order to reduce their seismic vulnerability.

Assessing the seismic vulnerability of buildings is essential in disaster preparedness, loss assessment and planning of retrofitting works on buildings that have insufficient levels of protection against seismic actions.

Although Bucharest, with an aging building stock, has the highest seismic risk of all European capitals, being considered as one of the 10 most earthquake-vulnerable cities in the world, there are still a low number of buildings that have been retrofitted.

In the last 20 years, retrofitting works were completed for only 97 buildings of 349 buildings classified in the 1st seismic risk class. Thus, in order to achieve buildings resiliency in earthquakes, a major and permanent measure is to accelerate the retrofitting process of vulnerable buildings.

To speed up the actions for setting up adequate intervention methods and to implement measures for reducing the vulnerability of buildings, it is essential either to adopt new provisions or to improve existing legislation. In this way, significant progress should be achieved, for facilitating access to different sources of funding, from both state budget and European or other international funds.

Considering the main directions of action set out by The Sendai Framework for Disaster Risk Reduction 2015-2030, related to the adoption of strategies and plans for disaster risk reduction and plans at national and local level, the concerns of the responsible authorities in the field of risk management should be mentioned. In order to ensure a robust strategic framework, the National Strategy for Seismic Risk Reduction, addressing all types of vulnerable buildings (public and private, residential and non-residential) and the National Strategy for Disaster Risk Reduction, supported by dedicated action plans and mechanisms for monitoring implementation, are under development. The elaboration and adoption of these strategies will strengthen the technical framework for implementing measures for seismic risk reduction, the prioritization of investments and the efficiency of institutional cooperation, in order to achieve a unified approach to risk management and the efficiency of joint actions for a building stock resilient to disasters.

REFERENCES

- [1] World Bank: *Preventable losses: saving lives and property through hazard risk management-Strategic framework for reducing the social and economic impact of earthquake, flood and landslide hazard in the Europe and Central Asia region*, 2004.
- [2] ***Proiectul *Evaluarea riscurilor de dezastre la nivel național (RO-RISK)*, cod SIPOCA 30, POCA 2014-2020, IGSU, 2016-2018.
- [3] ****Radiografie a Riscurilor de dezastre. Profilul riscurilor în România*, Revista Protecția Civilă, ISSN 1223-575X, 1: 19-21, IGSU, 2020.

- [4] Georgescu E.S., Craifaleanu I., Gociman C.O., Georgescu M.S., Moscu C.I., Dragomir C.S., *Urban Resilience Before, during and beyond disasters: Earthquake engineering and preparedness issues for Bucharest*, International Conference Romania, ISBN 978-606-154-3, 2016.
- [5] Lungu D, Aldea A., Demetriu S., Craifaleanu I., *Seismic strengthening of buildings and seismic instrumentation-two priorities for seismic risk reduction in Romania*, Acta Geodaetica et Geophysica Hungarica, 39: 233-258, 10.1556/AGeod.39.2004.2-3.8., 2004.
- [6] World Bank Report No. P-2240-RO, *Report and Recommendation of the President of the International Bank for Reconstruction and Development to the executive Directors on a Proposed Loan to the Investment Bank with the Guarantee of the Socialist Republic of Romania for a Post Earthquake Construction Assistance Project*, 1978.
- [7] Martino Pesaresi, Daniele Ehrlich, Thomas Kemper, Alice Siragusa, Aneta J. Florczyk, Sergio Freire, Christina Corbane, *Atlas of the Human Planet 2017: Global Exposure to Natural Hazards*, EUR 28556 EN, doi: 10.2760/19837, 2017.
- [8] Radu C., Polonic G., *Seismicity of Romanian territory with special reference to Vrancea region. In: The March 4, 1977 earthquake in Romania*, Editura Academiei Române, 1982.
- [9] Pavel F., Văcăreanu R., *Assessment of the Seismic Performance for a Low-Code RC Shear Walls Structure in Bucharest (Romania)*, Journal: The Open Construction and Building Technology Journal, 14: 111-123, 2020.
- [10] Georgescu E.S., Pomonis A., *New Archival Evidence on the 1977 Vrancea, Romania Earthquake and Its impact on Disaster Management and Seismic Risk*. In: Vacareanu R., Ionescu C. (eds) *Seismic Hazard and Risk Assessment*. Springer Natural Hazards. Springer, 281-295, 2018.
- [11] Georgescu E. S., *Bucureștiul și seismele*, Editura Fundației Culturale Libra, București, 2007.
- [12] Petrovici R., *Evoluția prevederilor de proiectare seismică pentru structurile și elementele nestructurale din zidărie în perioada 1963 – 2013*, Revista Construcțiilor, ISSN 1841-1290, 110:50-54, 2014.
- [13] ****Metodologie privind investigarea de urgență a siguranței postseism a clădirilor și stabilirea soluțiilor-cadru de intervenție, indicativ ME 003-2007*, OMDLPL nr. 127/08.05.2007, MOF nr. 562bis/16.08.2007, BC nr. 8/2007, MDLPL, 2007.
- [14] Văcăreanu R., Postelnicu T., Popa, V., Coțofană, D., Cheșca, B., Ionescu, R.: *Study on seismic performance of existing buildings in Romania*, Tehnical Report, The JICA Technical Cooperation Project in Romania, București, 2005.
- [15] Dubină D., Lungu D., *Construcții amplasate în zone cu mișcări seismice puternice*, Editura Orizonturi Universitare, Timișoara, ISBN 973-8391-90-3, 2003.
- [16] ****Cod de proiectare seismică - Partea a III-a - Prevederi pentru evaluarea seismică a clădirilor existente, indicativ P 100-3/2019*", OMDRAP nr. 2834/09.10.2019, Monitorul Oficial p. I, nr. 1003bis/13.12.2019, MDRAP, 2019.
- [17] United Nations Office for Disaster Risk Reduction, *Sendai Framework for Disaster Risk Reduction 2015-2030*.
<https://www.undrr.org/publication/sendai-framework-disaster-risk-reduction-2015-2030>