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DEFINING SEISMIC RESILIENCE WITHIN THE CONTEXT OF NORTH-EASTERN REGION OF ROMANIA

BY

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Abstract. This paper presents an overview of the resilience concepts, being focused on the seismic resilience linked to the North-Eastern region of Romania. This research theme is studied in varied and distinct disciplines, and in the engineering field is one of the most important issues because seismic resilience must be achieved in order to have a safety built environment.

Earthquakes produced in the Vrancea region affect a large part of Romania, but few studies have particularized the general framework of Vrancea earthquakes' effect on the Iaşi county, Iaşi municipality within N-E Romania context. In this manner, this paper analyses the situation of the Iaşi County related to the resilience against natural disaster, like earthquakes, and the actual state of the road network. For a right analysis, it is important to understand the resilience definitions, the way of quantifying it, the possible natural hazards that could affect the area and to identify the critical components in case of emergency situations. Using the resilience aspects is possible to improve the way engineers, planners and stakeholders design and evaluate the built environment.

The idea of building resilience to natural hazards, such as earthquakes, or man-made disasters is now a dominant research theme.

Key words: resilience; seismic resilience; natural disaster; earthquake.

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1. Introduction

No one is immune from disasters or disaster-related losses. In order to reduce the impacts of natural disasters upon the communities is needed to invest in enhancing resilience. For a better understanding, the resilience is defined like *the ability to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events* (Nat. Acad. of Sci., 2012). So that, resilience allows better anticipation of disasters and better planning in order to reduce disaster losses. The most important thing after a hazardous event is to maintain a resilient and robust community, and for these is necessary the implementation of a specific framework. Communities are vulnerable to a large number of natural and man-made hazards, including earthquakes, landslides, floods, economic downturns, and terrorist attacks.

This paper focuses primarily on seismic resilience, which is especially challenging because of the unpredictability and the disastrous impact of earthquakes. Seismic resilience describes the loss and loss recovery required to maintain the function of the structure with minimal disruption (Cimellaro *et al*., 2009). In addition, this paper is concentrated on the North-Eastern of Romania, being analysed the seismicity of the zone and the infrastructure elements that can be affected in case of eventual earthquakes.

2. Definition of Resilience

The literature about resilience is very useful to identify essential community functions that need to be maintained after a disaster. Most of the research in this field has focused on defining resilience and establishing metrics to quantify it.

Resilience to disasters is defined in the scientific literature in several ways. Tierney & Bruneau, (2007), define disaster resilience as "… *the ability of social units (e.g., organizations, communities) to mitigate hazards, contain the effects of disasters when they occur, and carry out recovery activities in ways that minimize social disruption and mitigate the effects of future disasters*".

Within hazards research literature, the definition of resilience is refined to mean the ability to survive and cope with a disaster with minimum impact and damage (Berkes, 2007). It contains the ability to reduce or avoid losses, moderate the effects of disasters, and recover with minimal social disruptions (Buckle *et al*., 2000). Resilience theme within hazards research is focused on engineers and social organizations, and includes pre-event measures to prevent hazard-related damage and losses (preparedness) and post-event strategies to help cope with and minimize disaster impacts (Bruneau *et al*., 2003).

Cimellaro *et al*., (2010), define resilience as ”… *a function indicating the capability to sustain a level of functionality or performance for a given building, bridge, lifeline networks, or community, over a period defined as the control time (T) that is usually decided by owners, or society*…”.

Bruneau *et al*., (2003), propose three complementary metrics to measure the resilience: probability of failure, the consequences of failure and recovery time. In the case of the earthquake hazard, a resilient system or subsystem can be characterized as one having a reduced likelihood of failure and failure consequences as the result of an event. These characterizations will involve considerations of the probabilities of an earthquake event, and the probabilities of structural failure modes, damage states, and consequences.

Fig. 1 (Tierney & Bruneau, 2007) illustrates the concept of resilience like a measure, $Q(t)$, that varies with time and has been defined for the quality of the infrastructure components of a community. If at time, t_0, occurs an earthquake the quality of the infrastructure is reduced by 100%, which means no degradation, to 50% of damaged structural state. Rehabilitation of the infrastructure is expected to occur over time, until time, t_1, when is completely repaired.

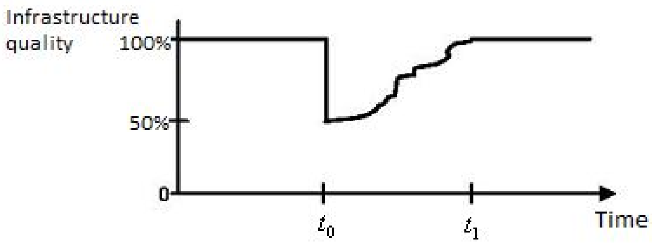

Fig. 1 – Measure of seismic resilience.

For studying resilience of systems and communities (Tierney & Bruneau, 2007) provided a framework based on four basic parameters – Robustness, Redundancy, Resourcefulness and Rapidity (Tierney & Bruneau, 2007) (R4 Framework)

a) *Robustness*: strength, or the ability of elements, arrangements, and other measures of analysis to withstand a given degree of stress or need without suffering degradation or loss of use.

b) *Redundancy*: the extent to which elements, systems, or other criteria of analysis exist that are substitutable, capable of filling the operational requirements in the event of disruption, degradation, or loss of functionality.

c) *Resourcefulness*: the capacity to identify problems, prioritizing them, and assign resources when it is necessary;

d) *Rapidity*: the capacity to meet priorities and achieve goals in a timely manner in order to control losses.

For making a quantitative evaluation of the resilience it is useful the TOSE framework (Tierney & Bruneau, 2007), which defines four dimensions or domains of resilience – Technical, Organizational, Social and Economic. The technical dimension of resilience refers to the ability of physical systems to perform to adequate degree when subjected to earthquake forces. The organizational dimension of resilience represents the ability of organizations that manage the situation in case of natural disaster to take the proper decision in order to achieve post-disaster resilience. The social dimension of resilience consists of measures designed to diminish the extent to which earthquake-stricken communities suffer negative consequences due to the loss of critical services as a result of earthquakes. The economic dimension refers to the ability of reducing direct and indirect economic losses resulting from earthquakes.

3. Seismic Hazard in North East of Romania

A hazard is defined as "any event or condition with the potential to cause fatalities, injuries, property damage, infrastructure damage, agricultural loss, environmental damage, business interruption, or other loss" (FEMA, 1999).

Romania territory is characterized by a large number of geographic forms and foundation soil types. The main potential natural hazard at country level relates to earthquakes, landslides and flooding. Table 1 (World Health Organization, 2001) shows a statistical distribution of the total population, around 21,190,154 people, that is exposed to natural hazards. The distribution is made by level of intensity.

Table 1
The Population Exposed to Hazards

Hazard	Hazard intensity levels and number and percentage of people exposed				
	Very high No. %	High No. %	Medium No. %	Low No. %	Very low No. %
Seismic	167,990 (0.79%)	5,146,753 (24.2%)	15,276,301 (72.0%)	599,104 (2.83%)	0 (0.00%)
Flood	207,577 (0.98 %)	8,480,444 (40.0%)	5,231,857 (24.69%)	1,826,574 (8.62%)	5,441,994 (25.6%)
Land-slide	0 (0.00%)	1,289 (0.01%)	1,407 (0.01 %)	8,650,601 (40.8%)	12,530,180 (59.1%)

Iaşi County is located in the North Eastern part of Romania. The town is characterized by a population of 290,422 residents, while the Metropolitan Area of Iaşi is home to 382,484 residents.

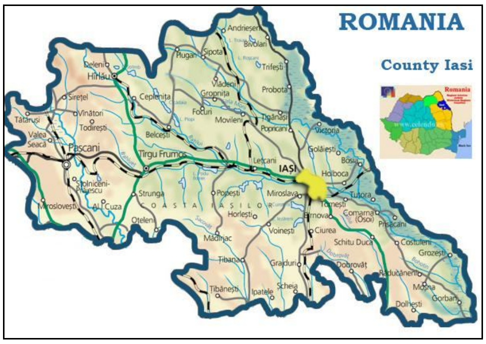

Fig. 2 – Iaşi County location.

The main potential natural hazards for Iaşi County refer to earthquakes, landslides and flooding. Iaşi city and county are included in the Vrancea seismic zone. The Vrancea (subduction) seismogenic zone is a peculiar intermediate depth source that strongly affects over 50% of the territory of Romania in case of each high magnitude earthquake.

The epicenters of earthquakes occurring within N-E Romanian territory must be known in order to make a complete and correct analysis of Iaşi region, in what concerns the earthquake effect. As it can be observed in Fig. 3 (Shebalin *et al*.,1998), municipality and county of Iaşi are not in the epicentral area, but

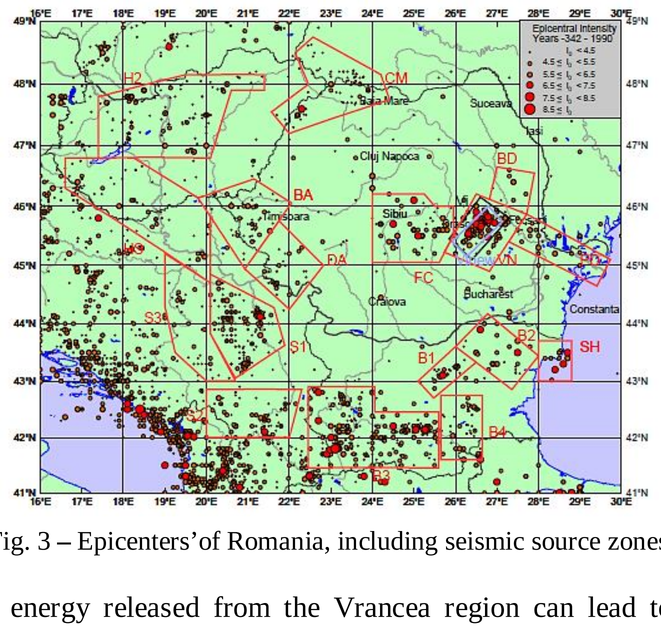

Fig. 3 – Epicenters'of Romania, including seismic source zones.

the seismic energy released from the Vrancea region can lead to disastrous consequences in case of large earthquakes. The strong seismic events originating from Vrancea can generate the most destructive effects experienced in Iaşi area, and may serious affect different structures and transportation network. The most direct effect of earthquakes involves physical damage to the built environment of a residential area. For instance, ground shaking can induce significant lateral displacements and accelerations that damage the structural elements in a building, possibly resulting in partial or total collapse of the structure.

4. Road Network of Iaşi County

The road network is an important part of the transport infrastructure and of terrestrial communication. As for transportation network, the management of natural hazards is administrated by the National Company for Highways and Roads in Romania (CNADNR) through its local subunits named Regional Direction for Roads and Bridges (DRDP). The National Roads Network of Iaşi County totalizes a value of 346.82 km and the spatial distribution can be observed in Fig. 4 (http://www.drdpiasi.ro, 2013). Iaşi Division has the highest number of National Road kilometers, but no highways, while Bucharest Division has the highest number of highway kilometers. If it is considered the particular case of an earthquake of high magnitude, IGSU notifies CNADNR and DRDP regarding the areas where the transportation has or might have suffered faults.

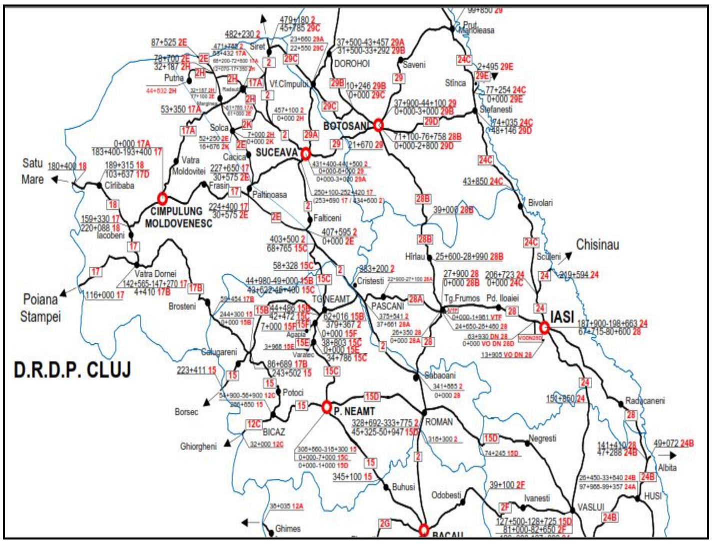

Fig. 4 – Roads Network in Iaşi region (Regional Direction for National Roads Iaşi).

In the case of Iaşi community, the infrastructural elements such as road power, water, hospital, and local emergency management systems, are tied together. The critical components in case of emergency situation are sketched in Fig. 5 (Bruneau *et al.*, 2003) with the link between them, and also for each of them are defined performance measures related to the technical and organizational dimensions.

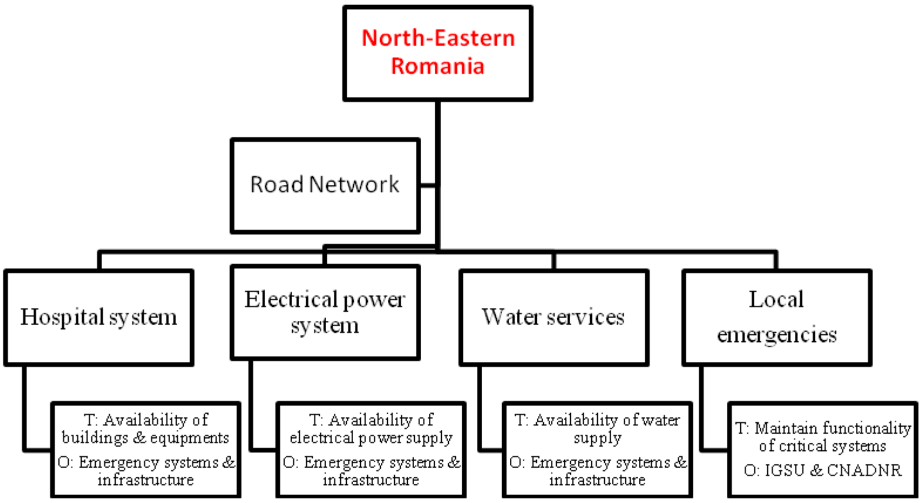

Fig. 5 – Critical components with their performance measures (adapted from Bruneau *et al.*, 2003).

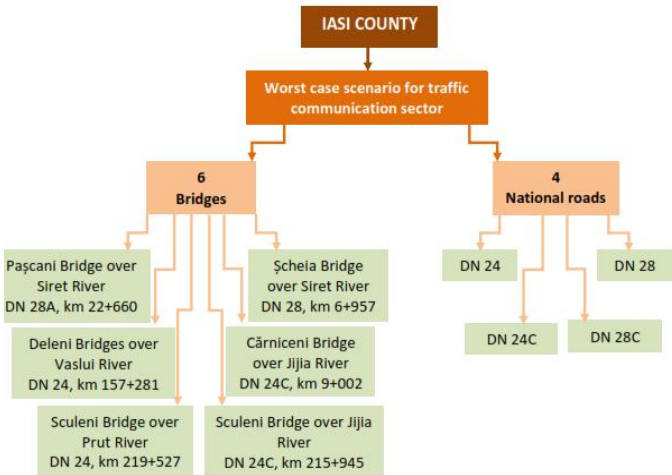

Fig. 6 – Critical components of road network, N-E Romania.

Severe damages to transportation infrastructure can have catastrophic impact on the ability of the community, business and economy to recover from a disaster.

If the North Eastern Romania is affected by a major natural hazard the main critical components of the road network are defined in Fig. 6, based on information given by the Regional Direction of Roads and Bridges.

5. Conclusions

The social and economic losses caused by extreme seismic events have increased in the last few decades the studies on seismic risk and resilience, aiming to develop new strategies to mitigate the destructive effects of such large earthquakes. The impact of a major Vrancea intermediate depth earthquake, affecting simultaneously approximately 50% of the territory, may produce strong direct damage, as well as indirect losses in other areas of the country, thus leading to a national disaster. This paper represents a beginning stage of studying about how to develop a regional strategy in case of major seismic events, where is needed to implement resilience aspects.

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DEFINIREA REZILIENȚEI SEISMICE ÎN CADRUL REGIUNII NORD-ESTICE A ROMÂNIE

(Rezumat)

Se prezintă o imagine de ansamblu asupra conceptului de reziliență, cu identificarea aspectelor privind fenomenul de reziliență seismică în contextul regiunii Nord-Estice a României. În ultimii ani, reziliența seismică a devenit un subiect mult abordat de către cercetători, mai ales de către cei din domeniul ingineriei seismice, dezvoltarea unui mod nou de gândire şi de planificare în domeniul proiectării construcțiilor fiind posibilă numai privind aspectele rezilienței seismice.

Regiunea de Nord-Est a României este expusă la cutremurele produse în zona Vrancei, multe dintre aceste evenimente fiind de magnitudine ridicată pe scara Richter. Ca urmare, abordarea rezilienței seismice în județul Iaşi este necesară atât sub aspect preventiv cât şi prin prisma eficientizării gestionării situațiilor de urgență în timpul şi imediat post-seism. Articolul abordează noțiuni esențiale privind reziliența, reziliența seismică, modul de cuantificare al acesteia, identificarea evenimentelor seismice extreme care ar putea afecta zona cu idenficarea şi a unor componente critice ale sistemelor de drumuri şi poduri, informații necesare în operațiunile de evacuare în siguranță a populației afectate.