

UNIVERSITATEA TEHNICĂ DE CONSTRUCȚII BUCUREȘTI

ȘCOALA DOCTORALĂ

DEPARTAMENTUL DE CONSTRUCȚII DE BETON ARMAT

Teza de Doctorat:

ANALIZA RISCULUI SEISMIC AL CLĂDIRILOR DE LOCUIT COLECTIVE CU
REGIMUL DE ÎNĂLȚIME P+4E DIN MUNICIPIUL CRAIOVA

Doctorand: ing. Alexandru-Robert VLĂDUȚ

Conducător de doctorat: prof. univ. dr. ing. Radu Sorin VĂCĂREANU

Septembrie 2026

RESUME

This work aims to address the issue of seismic risk associated with collective residential buildings with a height regime of GF+4 stories in the Municipality of Craiova. This building type was selected because it is very widespread in Craiova — over 2,550 buildings, housing approximately half of the city's population. Seismic risk and the effects of Vrancea earthquakes on Romania have been discussed in several studies, but mainly with reference to Bucharest, Iași, and Ploiești. Following the March 1977 earthquake, Craiova Municipality and Dolj County recorded the highest number of casualties and damaged buildings after Bucharest, despite an epicentral distance of more than 270 km.

Another example of earthquakes that affected buildings in Craiova is represented by the seismic events produced in the Gorj area in 2023, where two earthquakes with magnitudes greater than 5.0 were recorded: 5.2 ML (4.8 Mw) on 13.02.2023 and 5.7 ML (5.4 Mw) on 14.02.2023. These earthquakes generated a state of panic in Craiova even though they were shallow events and the epicentral distance was approximately 105 km. According to the Pool of Insurance Against Natural Disasters (PAID), about 5% of damage claims were registered in Dolj County and the Municipality of Craiova.

The general objective of the doctoral thesis is to bring to public attention an analysis of the existing building stock in Craiova in the context of future seismic risk reduction programs (the rapid visual screening program and the expert evaluation program for residential buildings constructed before 1977).

The thesis is structured into eight chapters.

Chapter 1 – Introduction provides a brief overview of the current issues of the existing building stock in Craiova, as well as a short summary of the main chapters of the work, presenting the main research directions.

Chapter 2 – Seismic Hazard Analysis presents an evaluation of the seismic hazard at the level of the Municipality of Craiova. Based on available literature, the chapter briefly describes Romania's seismicity, attenuation relationships used to estimate ground motion amplitudes, and the seismic motions recorded in Craiova during the Vrancea earthquakes of August 1986 and May 1990. Local soil conditions are also presented based on literature data and boreholes drilled in various areas of the city and its surroundings. The seismic hazard evaluation is performed using both deterministic methods and probabilistic analyses from the BIGSEES research project. Comparisons are made between observed macroseismic intensities in Craiova and those estimated using a model developed for the intermediate-depth Vrancea seismic source.

A liquefaction susceptibility analysis is also performed based on data from three boreholes in Craiova (Airport Platform, Ion Oblemenco Stadium, and 113 București Street). The analysis follows the Seed-Idriss / Idriss-Boulanger methodology for a scenario earthquake with $M_w = 7.5$ and $a_{max} = 0.2$ g. The results indicate liquefaction safety factors below unity only for the borehole near Ion Oblemenco Stadium, consistent with literature observations (Ishihara & Perlea, 1984) regarding liquefaction phenomena in the low Jiu river plain during the 4 March 1977 earthquake.

Chapter 3 – Impact of Vrancea Earthquakes on the Built Environment of Craiova and Surroundings presents the impact of Vrancea earthquakes on Craiova’s building stock, especially the 1977 event. Photographs, national reports, and studies by foreign experts who visited Craiova after the earthquake are included. The disproportionate impact on Dolj County, despite the large epicentral distance, is attributed to the advanced deterioration of the residential stock (old single-family houses with inadequate seismic resistance), local site conditions (Craiova lies on the Jiu river plain with over 50 m of loess deposits), and the exclusion of Dolj County—including Craiova—from the official seismic zoning between 1952/1953 and 1977, which led to buildings being designed without seismic provisions. The chapter concludes with a list of damaged collective residential buildings, including their location, number of buildings, height regime, structural system, and the sources of information.

Chapter 4 – Structural Typologies for GF+4S Buildings reviews the history of collective housing construction in Craiova and describes the structural typologies used before and after 1977. Buildings constructed before 1977 predominantly used unreinforced masonry bearing walls, built according to standard designs, with hollow-core precast slab strips supported on transverse walls. Reinforced concrete tie-columns, when present, were placed only at the ground and first floors, without continuity over the full height, since Craiova was not classified as a seismic zone. Large-panel precast concrete systems were also widely used (type 1013 project was used for over 40,000 apartments in Romania, including Craiova, between 1962–1968). After the 1977 earthquake, new technical instructions were adopted for large-panel buildings (ICCPDC, 1978), and additional requirements were imposed regarding minimum masonry wall lengths between openings and at wall edges (P2-75, then P2-85), as well as the placement of reinforced concrete confining columns.

Chapter 5 – Seismic Exposure of Buildings in Craiova evaluates the seismic exposure of buildings and dwellings in Craiova, focusing on GF+4S buildings. Exposure is assessed using three data sources: the 2011 building and dwelling census, the European seismic risk model ESRM2020 (Crowley et al., 2021), and technical data from Avram (1987). Significant discrepancies are identified between the number of masonry buildings reported in the 2011 census and those in ESRM2020—an observation also valid at national level (Pavel et al., 2022). Literature sources also disagree regarding the seismic protection level associated with code P100-92: Crowley et al. (2020) consider it “moderate,” while Lungu et al. (2002) consider it “advanced.” Based on the 2011 census

combined with ESRM2020, approximately 30% of GF+4S buildings in Craiova were designed with a pre-1977 seismic code, while the rest were designed with a moderate-level code; buildings constructed before 1960 or after 1992 are negligible in number. Two major limitations of ESRM2020 for Craiova are identified: (i) a gross overestimation of the share of reinforced concrete frame buildings—real values do not exceed 5%, compared to nearly half in ESRM2020—and (ii) incorrect classification of all masonry buildings as “confined,” although only post-1977 buildings fit this category, while pre-1977 buildings are unreinforced masonry. Based on these observations, the thesis proposes a corrected exposure model for GF+4S residential buildings in Craiova, useful for future large-scale seismic risk analyses.

Chapter 6 – Evaluation of the Building Stock Damaged in 1977 presents the medium-height buildings (GF+2S to GF+4S) damaged in 1977 and their current condition, along with structural observations. Repair and strengthening works were generally carried out, but often incompletely; the large number of strengthening projects executed only after 1990 indicates that initial interventions did not meet later code requirements (P100-81 and P100-92). In some buildings in Valea Roșie, damage migrated from strengthened floors (ground and first floor) to unstrengthened upper floors. The G+10 building in this neighborhood (reinforced concrete shear walls) shows diagonal cracks and parapet damage. Many affected buildings show cracks in slabs around stairwells—present at all levels, in at least three locations. Some strengthened buildings no longer show damage, and others did not record new damage during the 1986 and 1990 earthquakes. The high proportion of damaged buildings in Valea Roșie is also explained by the moisture sensitivity of the foundation soil (macroporous soils). GF+4S buildings with reinforced concrete wall structures did not suffer damage in 1977—the only undamaged structural system of this height in Valea Roșie.

Chapter 7 – Seismic Risk Assessment for GF+4S Buildings evaluates the seismic vulnerability of GF+4S structures in Craiova based on experimental results from literature and numerical analyses performed in a specialized software. This key chapter quantifies the seismic risk of the most vulnerable typology—GF+4S buildings with unreinforced masonry walls—using experimental data, the HAZUS methodology (FEMA, 2012), and pushover analyses. Seismic capacity was evaluated for a real GF+4S unreinforced masonry building (the only one with an available original structural design), located in Brazda lui Novac, designed in 1964, with reinforced concrete tie-columns only at the ground and first floors. The numerical model was developed in TreMuri (Lagomarsino et al., 2013) using an equivalent frame approach. Pushover analysis in both main directions showed small ultimate lateral displacements due to low tensile and shear strength of masonry and poor structural configuration (walls loaded in only one direction, large façade openings, low material quality). Based on capacity curves and the RISK-UE methodology (Milutinovic & Trendafilovski, 2003), fragility functions were developed for four damage states (slight, moderate, extensive, complete), separately for both directions.

For a design acceleration of $a_g = 0.20 \text{ g}$ (P100-1/2013, current hazard map for Craiova), at the performance point determined using the capacity spectrum method, the expected mean relative loss is 72.9% of the total replacement cost—an extremely high value confirming the severe seismic vulnerability of this widely distributed typology in Craiova.

Chapter 8 – Conclusions presents general and chapter-specific conclusions, personal contributions, and future research directions. Overall, the thesis aims to raise awareness regarding the existing building stock in Craiova and the need to reduce seismic risk associated with masonry wall structures of GF+4S height built before 1977.