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Improved seismic risk estimation for Bucharest, based on multiple hazard scenarios, analytical methods and new techniques

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Bucharest, capital of Romania (with 1678000 inhabitants in 2011), is one of the most exposed big cities in Europe to seismic damage. The major earthquakes affecting the city have their origin in the Vrancea region. The Vrancea intermediate-depth source generates, statistically, 2-3 shocks with moment magnitude >7.0 per century. Although the focal distance is greater than 170 km, the historical records (from the 1838, 1894, 1908, 1940 and 1977 events) reveal severe effects in the Bucharest area, e.g. intensities IX (MSK) for the case of 1940 event. During the 1977 earthquake, 1420 people were killed and 33 large buildings collapsed.
The nowadays building stock is vulnerable both due to construction (material, age) and soil conditions (high amplification, generated within the weak consolidated Quaternary deposits, their thickness is varying 250-500m throughout the city). A number of 373 old buildings, out of 2563, evaluated by experts are more likely to experience severe damage/collapse in the next major earthquake. The total number of residential buildings, in 2011, was 113900. In order to guide the mitigation measures, different studies tried to estimate the seismic risk of Bucharest, in terms of buildings, population or economic damage probability. Unfortunately, most of them were based on incomplete sets of data, whether regarding the hazard or the building stock in detail. However, during the DACEA Project, the National Institute for Earth Physics, together with the Technical University of Civil Engineering Bucharest and NORSAR Institute managed to compile a database for buildings in southern Romania (according to the 1999 census), with 48 associated capacity and fragility curves. Until now, the developed real-time estimation system was not implemented for Bucharest.
This paper presents more than an adaptation of this system to Bucharest; first, we analyze the previous seismic risk studies, from a SWOT perspective. This reveals that most of the studies don't use a very local-dependent hazard. Also, for major earthquakes, nonlinear effects need to be considered. This problem is treated accordingly, by using recent microzonation studies, together with real data recorded at 4 events with Mw$\geq$6. Different ground motion prediction equations are also analyzed, and improvement of them is investigated.
For the buildings and population damage assessment, two open-source software are used and compared: SELENA and ELER. The damage probability for buildings is obtained through capacity-spectrum based methods. The spectral content is used for spectral acceleration at 0.2, 0.3 and 1 seconds. As the level of analysis (6 sectors for all the city) has not the best resolution with respect to the Bucharest hazard scenarios defined, we propose a procedure on how to divide the data into smaller units, taking into consideration the construction code (4 periods) and material. This approach relies on free data available from real estate agencies web-sites.
The study provides an insight view on the seismic risk analysis for Bucharest and an improvement of the real-time emergency system. Most important, the system is also evaluated through real data and relevant scenarios. State-of-the art GIS maps are also presented, both for seismic hazard and risk.