Overview of Part IV: Seismic Evaluation and Rehabilitation. Seismic Risk Assessment

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This chapter includes papers that deal with the seismic evaluation and rehabilitation of existing buildings in Romania and neighbouring countries- e.g. Republic of Moldova, using both fundamental and cutting-edge approaches.

The seismic assessment and rehabilitation of existing constructions after the 10th of November 1940 and 4th of March 1977 earthquakes in Romania are investigated in a very practical approach, presenting the main concepts, the analysis methods and the strengthening methods used for existing structures. Two examples of such structures, one from Bucharest, the other from Focsani, are thus discussed in the paper entitled "Seismic Assessment and Rehabilitation of Existing Constructions After the 10th November 1940 and 4th March 1977 Earthquakes in Romania". The authors conclude that the original method, based on energy concepts to judge the failure criteria for resistance and deformation, by comparing the surface of member's capacity, for a single degree of freedom model of various multi-story constructions, to the surface required by the building response to different types of earthquakes, is still valid today. The failure theories, based on the energetic model from strut-tie models, or taking into consideration the areas in which the theories based on the continuous, homogenous and isotropic body hypothesis cannot be applied, for which specific finite element models apply for the potential cracking areas or probabilistic models with the aid of fragility curves, are all analysis methods of medium or greater complexity which are necessary to be applied for the structures or areas of structures of important constructions and which will be developed more in the future.

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In the paper entitled "Some Remarks Regarding Seismic Vulnerability for Orthodox Churches" the sensitive problem of seismic evaluation of historical buildings is treated using cutting-edge approaches. The large number of existing and unique historical monuments in Romania draws the attention over the importance of rehabilitation and conservation works that need to be carried out in order to prevent their damage. The global concern regarding the conservation of world heritage is obvious if the ongoing projects would be considered. Integrated Rehabilitation and Research on Architectural and Archaeological Heritage (IRPP/SAAH) is one of the main projects in this field, in which a priority list was made containing 186 architectural monuments and archaeological sites from nine participating countries, which need to be rehabilitated. In the paper the authors present an analysis of the seismic vulnerability of masonry orthodox churches located in Moldavia region. Old masonry structures were considered and a comparison between the three main types of churches is shown—churches with rectangular, trefoil or Greek cross plan configuration. Structural vulnerability analysis for the considered typologies is done based on nonlinear static analysis (pushover). Vulnerability and fragility curves for the analyzed structures are plotted based on the results and on the well-known methodology. The paper also discusses the way of reducing the risk of casualties caused by the vulnerability in case of a mass gathering of people. In this respect, numerical simulations are performed for the analysis of evacuation time required in relation to a certain level of structural response, for the three types of the considered structures.

The paper entitled "The Effects of an Analogous to November 10, 1940 EQ Over the Buildings Stock in Republic of Moldova", presents an estimation of seismic-induced damage in the Republic of Moldova through a comprehensive Damage-Loss Methodology. The territory of the Republic of Moldova has been suffering heavy damages and losses as a result of the activity of the intermediate depth earthquake sources located in the area of Vrancea region, Romania. The severity of these earthquakes, combined with limited resources, has a significant negative impact on the population and infrastructure of the Republic of Moldova. The Vrancea earthquake of November 10, 1940 was selected as the earthquake scenario—the strongest event occurred in the 20th century. The total number of buildings taken into account into analysis is about 1.5 million units. The potential loss was represented in damage terms through the "the average damage grade". The authors conclude that in Moldova there are areas presenting high probability of large damage caused by future strong earthquakes. Weaknesses concerning seismic safety in the Republic of Moldova as well as the necessary preventive scientific, political, administrative measures have been also listed.

Another work addressed to the nowadays consequences of an earthquake similar to the November 10, 1940 event is "Seismic Loss Estimates for Scenarios of the 1940 Vrancea Earthquake". Using the newly implemented System for Estimating the Seismic Damage in Romania operated by NIEP, (SeisDaRo), authors estimate the possible damage caused by scenarios of this earthquake. In order to provide a reasonable dimension of the possible accelerations and their distribution over the territory of Romania, 3 ground motion prediction equations developed especially for Vrancea intermediate-depth events have been selected. An analytical methodology (Improved Displacement Coefficient Method) implemented in SELENA software has been used to estimate direct seismic losses. Vulnerability data comes from the last available census and consists in number of buildings for 1400 territorial administrative zones/units (cities, communes or sectors of Bucharest) located in the extra-Carpathian area. For each TAZ 48 building types are identified (depending construction materials, height classes and construction periods) with their associated capacity and fragility curves and corresponding number of residents per building type. The damage estimates for each ground motion scenario are presented on relevant maps, discussed and compared with the ones reported after the November 10, 1940 event. Authors conclude that a similar earthquake nowadays will produce greater damage and mitigation actions are much required. Seismic risk analyses in Romania are focused mainly on buildings (which concentrate most of the damage). Also, many studies refer to the action of earthquakes on bridges and/or other individual infrastructure elements that require special design and analysis. Much less (published) work is treating in an applicative manner the impact of earthquakes on transportation network.

The paper entitled "Conceptual Framework for the Seismic Risk Evaluation of Transportation Networks in Romania" is an attempt to identify viable ways to analyse the seismic risk of transportation networks, considering the availability and characteristics of specific data, the possibilities of adapting external knowledge and new methodologies recently developed. The integrative framework described here incorporates GIS capabilities (ArcGIS Network Analyst Toolbox), fragility functions for critical structures (bridges, tunnels) used for estimations of the damage level and traffic characteristics in order to analyse the connectivity and capacity of the transportation network to accommodate the demand in post-earthquake context. The proposed quantification of risks is based on comparison between performance indicators estimated for the undamaged network and the damaged one in order to identify critical elements and to improve its configuration. Framework's applicability to Romania is tested for the case of Bucharest by using mostly public information available for road networks. Results are presented in suggestive maps for intervention times (ambulances and for fire trucks) or fastest routes between northern and southern Bucharest for emergency intervention vehicles, considering various scenarios. Further developments/improvements of the traffic modelling are proposed and discussed.

Modern approach in mitigation of seismic risk requires not only the decrease of seismic vulnerability of the build environment but also preparedness measures and planning of the emergency reaction. The paper "Rapid Earthquake Early Warning (REWS) in Romania: Application in Real Time for Governmental Authority and Critical Infrastructures" presents the Romanian Rapid Early Warning System (REWS) operational since 2013. REWS is sending alerts and notifications to the emergency response authorities, emergency centres from ministries and also to critical nuclear infrastructures (nuclear research facilities, power plants and other similar activities). Recent technical upgrades of seismic equipment and rapid communication together with research on methodologies to estimate magnitude allows a rapid broadcast of alerts. Using only 4 s of data after P wave detection in epicentral area, REWS is rapidly locating and estimating the magnitude; alert is issued only if the magnitude of the seismic event is larger than 4. Taking into account that Vrancea intermediate depth events can produce extensive damages to neighbour countries, the REWS is sending alerts also to the Bulgarian Civil protection and Kozloduy nuclear power plant. Up to now, 19 alerts have been issued by REWS and no false alerts recorded. The performance and present development of the REWS is suitable to send alerts according to the user requirement in order to activate systems that can contribute to risk reduction before the dangerous waves reach the target area.

In the paper "Analytical Seismic Fragility Functions for Dual RC Structures in Bucharest" the issue of fragility functions is tackled using the analytical approach. To this aim incremental dynamic analyses are performed on two dual RC mid-rise and high-rise building structures designed according to the relevant codes in force in Romania. The buildings have the same horizontal layout with five spans of 8.00 m in both orthogonal directions. The nonlinear time history analyses required by the incremental dynamic analysis method are performed with STERA 3D ver. 5. 8. The hysteretic model employed is a trilinear degrading one based on the Takeda model. The input ground motions for the nonlinear time history analyses are 75 horizontal components of site-dependent simulated accelerograms that are randomly selected from a larger set developed for the INCERC site in Bucharest. The selected site is characterized by predominant long-periods of vibration of soil in strong earthquakes and the simulated accelerograms are reproducing this trend. The analytical fragility functions are obtained using the results of NTHAs. The conditional intensity measures of the fragility functions are the peak ground acceleration and the spectral response values at the fundamental period of vibration of the buildings. The fragility functions are developed for both damage states and limit states and are fully defined by the median values and the lognormal standard deviations of the intensity measures.