From Seismic Instrumentation Towards Disaster Prevention and Mitigation

Claudiu Sorin Dragomir¹, Daniela Dobre²

¹University of Agronomic Sciences and Veterinary Medicine, Faculty of Land Reclamation and Environment Engineering. National Institute for Research and Development URBAN-INCERC Bucharest, Romania
²Technical University of Civil Engineering Bucharest. National Institute for Research and Development URBAN-INCERC Bucharest, Romania

claudiu.dragomir@fifim.ro

Abstract. The present paper describes the current technical achievements in seismic instrumentation and monitoring within a national network and the role of this developed concept in disaster prevention and mitigation, in particular case of Romanian seismicity. Many studies are being conducted in the field of structural health monitoring, for seismically instrumented/monitored buildings, based on existed sensor technology, seismic data acquisition systems, data communication and information flow, computer hardware/software engineering, new solutions for seismic data transfer etc. Seismic records in free-field and on buildings are capitalised in anti-seismic design, development of technical and technological solutions in construction, seismic evaluation and rehabilitation of buildings, as well as in the process of education and earthquake preparedness. It aimed also to create a virtual seismic network (through Internet, WAN property networks, public analogue telephone network). It is a national priority creating a preventive culture in order to mitigate the seismic risk, starting with the strengthening of buildings, upgrading of the code for seismic design, seismic instrumentation as a usual practice and continuing with public communication and information actions, empowering communities and decision-makers related to the risks, prevention measures, what behaviour to be adopted. The efforts of last years show that Romania has taken important steps in preparing a response according to the challenges induced by the existing seismic sources from the entire territory of the country.

1. Introduction
Determining the seismic resistance of the built environment is part of any plan to reduce the effects of earthquakes, generating intelligent urban systematization, operationalizing interventions after a severe earthquake in certain areas, knowing vulnerability, supporting the sustainable development of a society.

The importance of measures to prevent seismic damage and their rapid identification after an earthquake is crucial to saving lives and reducing material losses. This fact is of particular relevance for Romania, a country whose territory is affected by severe earthquakes from Vrancea source.

Temporary instrumentation (or permanent monitoring) of a building, under the conditions specified by codes P130 / 1999 and P100-1/2013, represents a necessity fulfilled by the studies elaborated
within many projects. Completing the database of recorded and processed data, from the locations where seismic sensors have been installed (free-field, or in buildings), provides a clearer picture of the level of local accelerations, specific to different soil conditions, and compared to the acceleration values in the seismic zoning map. Through the permanent seismic monitoring of a building, in the future earthquakes, it will be possible to carry out advanced analyses through which it will be possible to establish quickly if the building has suffered structural damages.

From a practical point of view, immediately after a future strong earthquake, a public institution, or a company with valuable buildings, will be interested in determining as soon as possible the state of health of its own headquarters and other buildings, if there is a prior implementation of an instrumentation / monitoring system.

2. National approach and experience
Within National Network for Monitoring and Seismic Protection of the Built Heritage (NIRD URBAN- INCERC), figure 1, some stages are taken into consideration in order to achieve an integrated system to ensure the security of the built space:

- selection of locations and installation of seismic stations for seismic instrumentation (tall buildings, buildings of public authorities); selection criteria are numerous and must be applied taking into account the possibility of obtaining the agreement from the owner institutions, their owners [1];

- research related on the identification and implementation of the seismic data transfer system: types of connections existing within and of course the identification and implementation of solutions for ensuring the transfer of seismic data [2];
studies on the identification and acquisition of equipment suitable for monitoring in compatibility with the other segments of the monitoring system, e.g. integration in the seismic data transmission system provided by the Special Telecommunications Service;

- rapid assessment of the vulnerability of instrumented buildings, based on measurements of environmental vibrations and earthquakes, the location, evolution and extent of damage; highlighting the history over time of the reduction of rigidity in the damaged element [3];
- establishing and implementing the logic scheme and the analytical model used in estimating structural damages and mechanism of failures;
- semi-automatic generation of peak ground acceleration maps from seismic actions or other vibratory sources.

3. Results and discussions
A large number of buildings have instrumented over time and what is very important an extensive program of seismic instrumentation of public buildings is in progress for many years. The permanent seismic instrumentation of some buildings was carried out, belonging to the importance categories I and II in accordance with the current seismic design code, indicative P100-1: 2013. In the first phase, the temporary seismic instrumentation of the buildings has performed in order to determine their dynamic characteristics. The identification of the buildings has made based on the established selection criteria.

Afterwards, buildings belonging to different structural typologies have selected:

- apartment blocks with mixed reinforced concrete structure (height regime basement, ground floor and 10 levels);
- office building with mixed reinforced concrete structure, or dual system (height regime basement, ground floor and 14, or 15 levels);
- office building with reinforced concrete structural walls (height regime basement, ground floor and 3 levels);
- heritage building cathedral, structural system from 1910-1912; 1932-1933; 1974-1982;
- heritage building monastery, structural system from 1622...1637
- buildings of research institutes and educational institutions (height regime basement, ground floor and 3 levels);
- General Inspectorate for Emergency Situations building etc.

From the point of view of the technical connections made in order to transmit data in real time/physical data/local system/connections, are mentioned:

- outdoor/indoor unit, WIMAX antenna, ETNA2 accelerometer; connection through the WIMAX subscriber terminal, with communication in the STS network;
- Huawei model router, Tp-link switch, ETNA accelerometer; connection in mobile phone network;
- outdoor/indoor unit, WIMAX antenna, GRANITE Kinematics accelerometer; connection through the WIMAX subscriber terminal etc.

Another aspect is related to identification of public buildings in view of instrumentation (temporary) / monitoring (permanent). Addresses were sent to all prefectures, from the country and Bucharest, for the temporary instrumentation of the headquarters, respectively for the seismic
monitoring in case they will acquire their own equipment (seismic sensors), including the real-time data transmission system. They will also be sent to the mayors and the temporary seismic instrumentation of all NIRD headquarters under the coordination of ministry of resort is considered, according to a pre-established schedule.

**Good practices in increasing the level of structural safety.** Examples of monitored building typologies, figure 2…7:

![Figure 2. St. Alexander and St. Nicholas Cathedral (historical heritage monument 1910-1912; 1932-1933; 1974-1982). The locations of the recording equipment (Location no. 1 - elevation 0.00; Location no. 2 - base of the tower; Location no.3 - upper part of the tower)](image)

By using sensor technologies and incorporating these into seismology and building infrastructure is an important step forward in understanding and responding to the status of built environment before, during, and after an extreme seismic event. New information on what is happening within a building, by incorporating high-density seismic instrumentation, both at the ground level and on upper floors, at any moment, can be used to make manual and automated real-time decisions. Within the National Network for the Seismic Monitoring and Protection of Building Stock from INCD URBAN-INCERC, the recent research studies are conducted in the field of digitalization of structural health and seismic monitoring of buildings having as object real buildings, seismically instrumented with modern equipment.
Figure 3. Instrumentation and monitoring a research institute. Tri-axial sensors installed on the 3rd floor and, respectively, the sensor installed outside the building.

Figure 4. General Inspectorate for Emergency Situations
Figure 5. ETNA 2 seismic equipment installed in the buildings of General Inspectorate for Emergency Situations

Figure 6. Ministry of Research, Innovation and Digitalization building

Figure 7. ETNA 2 seismic equipment installed in the buildings of Ministry of Research, Innovation and Digitalization
4. Processing of records obtained at General Inspectorate for Emergency Situations

At the seismic station installed at the level of the terrace, in the continuous ringbuffer records, the earthquake produced on 09.04.2021, the local time of Romania 21:38, with a magnitude of 4.5 ML according to the site www.infp.ro, was identified.

By processing this recording using Strong Motion Analyst software, time histories were obtained for accelerations, velocities and displacements, figure 8, produced on site by the seismic event mentioned above. Advanced processing in order to identify the dynamic characteristics of the building was done. Thus, the response spectra and the Fourier spectra specific to the recording channels, figure 9 and figure 10, were obtained.

![Figure 8. Time histories for accelerations, velocities and displacements recorded for 3 channels](image)

![Figure 9. Velocity response spectra for 3 recording channels](image)

![Figure 10. Acceleration response spectra for 3 recording channels](image)

Following the analysis of the Fourier and response spectra for the recordings of three channels, the values of the oscillation frequencies for the two main directions are: $f_1 = 1.60$ Hz and $f_2 = 1.50$ Hz.
5. Conclusions

By using sensor technologies and incorporating these into seismology and building infrastructure is an important step forward in understanding and responding to the status of built environment before, during, and after an extreme seismic event. New information on what is happening within a building, by incorporating high-density seismic instrumentation, both at the ground level and on upper floors, at any moment, can be used to make manual and automated real-time decisions.

Research conducted in NIRD URBAN-INCERC converges towards the development of a large monitoring system capable, in the future, to allow remote identification, in a very short time after a seismic event, of possible dangerous changes in the condition of the building. The completion of the registered and processed data, from the sites where seismic sensors (free-field type, or in buildings) were installed, specific to different soil conditions and soil-structure interaction and of compared to the values of the accelerations from the seismic zoning map.

Digitalization of structural health and seismic monitoring of buildings are active research approaches from which the dynamic characteristics will be obtained in structural identification and a damage detection could be possible using a specialized software. All financial investments in this field will lead to a dense network from which useful information related to the behaviour of structural systems will make possible the adoption of measures to increase urban resilience.

Acknowledgment(s)

Results are part of the project “Research on the implementation of an integrated system for ensuring the security of the constructed space, with semi-automatic generation of PGA maps provided by seismic actions or other vibratory sources and quick evaluation of vulnerability of instrumented buildings” (PN19 33 01 01).

References
[1] C.-S. Dragomir, and D. Dobre, Selection criteria for investigation of microseismic and ambient vibrations. Case studies, 17th International Multidisciplinary Scientific Geoconference & Expo SGEM, Albena, Bulgaria, 2017.
[2] C.-S. Dragomir and D. Dobre, Improvements in a smart monitoring system for buildings, XXth International Multidisciplinary Scientific GeoConference Surveying, Geology and Mining, Ecology and Management - SGEM 2020, Albena, Bulgaria, 2020.
[3] C.-S. Dragomir, D. Dobre and V. Iliescu, A comprehensive approach for the seismic vulnerability of a building of public utility, IOP Conference Series: Materials Science and Engineering, vol. 960, issue 4, pp. 042073, IOP Publishing.
[4] C.-S. Dragomir, I.-G. Craifaleanu, V. Meita, E.-S. Georgescu, D. Dobre, M. Sandu and A. Cismelaru, 15th International Scientific Conference CIBv - Civil Engineering and Building Services 2020, paper no. 38, Brasov, Romania, 2020.