Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. VI, 2017
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

EX-ANTE AND EX-POST INSTRUMENTAL DIAGNOSIS OF BUILDINGS STRUCTURAL HEALTH, AN APPROACH AT THE LEVEL OF THE NATIONAL SEISMIC NETWORK, ”URBAN-INCERC”

Claudiu-Sorin DRAGOMIR[1,3], Daniela DOBRE[2,3], Iolanda-Gabriela CRAIFALEANU[2,3], Emil-Sever GEORGESCU[3]

[1]University of Agronomic Sciences and Veterinary Medicine Bucharest, Romania
[2]Technical University of Civil Engineering Bucharest, Romania
[3]National Institute for Research and Development in Construction, Urban Planning and Sustainable Spatial Development "URBAN-INCERC", Bucharest, Romania

Corresponding author email: dragomirclaudiusorin@yahoo.com

Abstract

Dense seismic instrumentation and modern devices are a prerequisite to making accurate observations on seismicity and its effects on buildings. In-situ instrumental data contribute to a correct understanding of the importance and of the influence of various factors on the structural dynamic response, as well as their correlation with interest objectives for the building owners/beneficiary. Romanian experience in INCERC after 1977 has demonstrated that damage to buildings was correlated with some changes in the oscillation periods of buildings. This distinction serves to decouple the influences that these Vrancea seismic motions have exercised successively and/or cumulative on the damage state. The rigidity and the values of oscillation periods are influenced not only by visible degradation, but also by a series of deformations and invisible cracks, accumulated in the building structure, which may be significant. In this regard, the determination of the dynamic characteristics of building structures is one of the most important aspects of structural health monitoring.

***Key words**: multichannel station, seismic instrumentation, structural health monitoring.*

INTRODUCTION

The main objective of this study is the improvement of the security and resilience of building stock to earthquakes and extreme actions.

The increasing safety is based on instrumentation and monitoring, primarily of the buildings with essential functions and/or buildings that pose a major threat to public safety in case of collapse or serious damage. In-situ assessment of the main dynamic characteristics of structures is one of the most important aspects of structural health monitoring.

The concept of the proposed evaluation is based on an algorithm for the interpretation of dynamic characteristics evolution with time. The results of the evaluation will be used in a communication campaign for raising awareness of owners and local authorities concerning the need for seismic instrumentation and monitoring of buildings for identifying the “initial” dynamic characteristics.

These characteristics will provide an essential reference for comparison, in the perspective of further structural safety assessments after an important seismic event (Borcia and Georgescu, 2005).

EX-ANTE AND EX-POST SEISMIC RECORDINGS AND OBSERVATIONS

The ex-ante monitoring of evolution of dynamic characteristics can be achieved by vibration instrumentation, as a requirement of structural safety assessment (Georgescu and Borcia, 2005; Borcia, 2006; Georgescu et al., 2014).

From technical point of view, it involves the deployment of a sensor network, used for oscillation recording and connected to a central station, allowing the real-time data management. Such network is deployed in parallel with the network of accelerometers located in small buildings (according to ANSS 2001 classification) or similar to free-field conditions (Craifaleanu et al., 2011). As it was previously reported, at present, the National Strong Motion Network for Constructions of URBAN-INCERC (in Romanian - RNSC) consists of 55 accelerometers, located in 45 localities in Romania (Dragomir et al., 2016).

The ex-post survey has shown that during strong earthquakes, many usual buildings were loaded beyond the elastic range. As a consequence, a significant change of their dynamic characteristics may occur, due to the alteration of physical-mechanical characteristics.

Thus, such a structural damage involves the decrease of building stiffness and the increase of natural periods. Consequently, the measurement of vibration periods in different situations, i.e. after building construction completion, during normal service, after earthquakes shaking, following retrofitting or other building interventions, allow a straightforward assessment of the damage degree.

The goals of the network and of the pertaining infrastructure are manifold, aiming not only at ground motion recording, but also, in a larger perspective, at the improvement of the security and resilience of building stock to earthquakes and extreme actions. In this respect, a system for monitoring and displaying recorded ground motion data in real time is envisaged, in conjunction with data provided by the devices from instrumented buildings.

Recently, a plan for real-time transmission of the recorded seismic data was developed in collaboration with the Romanian Special Telecommunication Service. Accordingly, starting from November 15th, 2015, 32 seismic stations, of which 4 in Bucharest and 28 distributed throughout the country, are connected to real-time data transmission (Dragomir et al., 2016).

This is provided both for stations located in free field-type conditions and for monitored building structures.

CASE STUDY OF SEISMIC INSTRUMENTATION OF AN EDUCATIONAL BUILDING

The object of study presented in Figure1 is of the Biotechnology Faculty building from Bucharest. The structural system of the buildings with basement, ground floor and 2 levels (B+G+2F) and it is made of reinforced concrete frames (columns and beams) and reinforced concrete structural walls, slabs and stairs. It has a semi-circular shape and the levels over ground are in cantilever related to those from the lower level.

Figure 1. The Biotechnology Faculty building from Bucharest

In this case, the in-situ seismic structural instrumentation/monitoring system were devised for a new built building of the faculty. The ex-ante instrumental diagnosis of structural health of buildings was based on micro tremors data processing and determination of natural vibration periods corresponding to two horizontal directions and to torsion in plane identified from Fourier spectra. Thus, the ex-post instrumental diagnosis of structural health of buildings will be based on a new set of dynamic measurements.

This information is particularly useful to assess the evolution of building stiffness.

All recordings have been obtained at the site, following the acquisition of data, from seismic monitoring equipment in the building, by transmission in real-time to the main server.

The data acquisition system is presented in Figure 2.

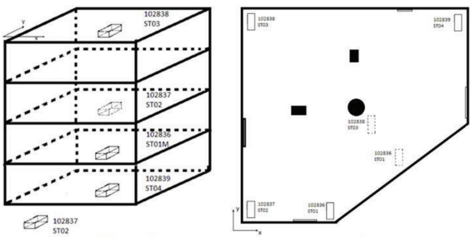
Figure 2. The data acquisition system with four GMS Plus digital seismic stations used for temporary seismic instrumentation of the new building of Biotechnology Faculty from Bucharest, B+G+2F (5 bays of 5.00 m and 5 openings of 5.00 m; H_{gf} = 3.80 m, H_1 = 4.10 m)

In Figure 3, a schematic plan with the equipment positioning is presented (location sensors).

Scheme 1: first option, with sensors in free-field, basement, ground floor and terrace level and, in the second option, one sensor is moved from free-field to level 1 (dotted line).

Scheme 2: first option, with all sensors on terrace level of building, at corners, and in the second option two sensors are moved in another position (dotted line).

By this seismic investigation, the effects as bending, torsion, horizontal stiffness of the floors; vibration frequencies etc. are monitored.



Scheme 1 *Scheme 2*

Figure 3. Geo SIG GMS Plus equipment positioning, vertically and horizontally

RESULTS AND DISCUSSIONS

For estimating the fundamental period of this building, the following formula is used:

$$T_1 = Ct\, H^{0.75} = 0.15\text{s}$$

where

$C_t = 0.075/\sqrt{(A_c)}$

A_c = the total effective area of structural walls on the 1st floor (approx. 13 m^2, on both directions)

H = the height of building (12.85 m)

From several series of recordings and from Fourier response spectra, corresponding to the direction X and Y, the predominant period T_1 is 0.18 s (Figure 4).

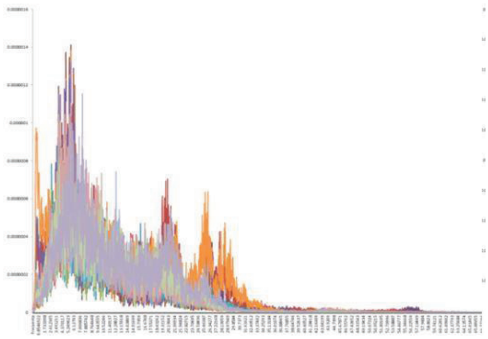


Figure 4. Fourier Response spectra, corresponding to the direction X and Y, from several series of recordings. Predominant period T_1= 0.18 s

For the validation of the FFT value f_1= 5.47 Hz, the ARTeMIS software was used and the results of f_1= 5.08 Hz are emphasised in Figure 5.

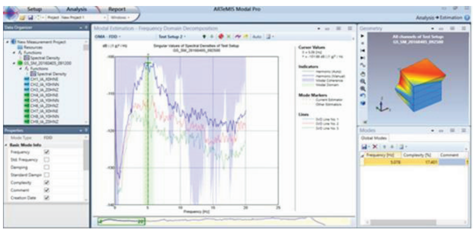


Figure 5. The results obtained using the Operational Modal Analysis, FDD technique

Some more experimental research related to types of soils and geological conditions are necessary, as well as the vibrations and strategies control for seismic energy dissipation, to evaluate the influence of construction materials properties etc., in order

Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

to get a better interpretation of seismic performance level of a building.

CONCLUSIONS

A case study of the Biotechnology Faculty building in Bucharest is presented. The structure is located in potentially unfavourable soil conditions, thus it was monitored for vibrations occurring from different seismic and non-seismic sources. This building was proposed for the seismic instrumentation in real time condition, in order to gather as many as possible data before strong motions.

The database will be useful after future strong earthquakes, when timely decisions on safety and functioning will be required.

Through a direct analysis, two sets of values will be compared and a possible structural damage due to a reduction in rigidity of the structure in question will be identified. After repairs/interventions, as after other smaller events, replicas, the new vibration periods will be of interest. If an increase in stiffness by comparing fundamental periods is not identified (increase of stiffness means reduction of vibration period), perhaps that structural intervention is not quite effective and so comparisons can be shown.

The newly-upgraded vibration monitoring and data communication/processing infrastructure of the National Seismic Network of URBAN-INCERC allows real-time transmission of data recorded on instrumented buildings, with application to structural identification, structural health monitoring and post-earthquake damage assessment.

Presently, an urgent necessity in Romania is an expanded seismic network in order to get as much as possible ex-ante data for advanced research and ex-post data from field surveys to understand why damages in buildings occurred. Since the large magnitude intermediate Vrancea earthquakes occur only at decades, the current motions of mid-size magnitude are very useful.

The next goal is to have more parametric and spectral data for engineering design, as well as to improve the zoning maps, having more stations at reduced distances.

ACKNOWLEDGEMENTS

This paper is based on some results obtained in Core Program PN 16 10.01.01, financed by the Romanian National Authority for Research and Innovation (ANCSI).

REFERENCES

Borcia I.S., Georgescu E.S. (2005): Seismic monitoring of buildings: prerequisites, case study and perspectives, Informative Bulleting of the National Commission “In Siu Behavior of Buildings”, CISC, year IX, Issue 4 and 5, Bucharest, 2005, ISSN: 1584-6687 (in Romanian).

Borcia I.S. (2006): Processing of strong motion records specific for the territory of Romania, *Ph D Thesis, Technical University of Civil Engineering*, Bucharest, Romania.

Craifaleanu I.G., Borcia I.S., Praun I.C. (2011): Strong-Motion Networks in Romania and Their Efficient Use in the Structural Engineering Applications”. In S. Akkar, P. Gülkan & T. van Eck (eds), *Earthquake Data in Engineering Seismology. Predictive Models, Data Management and Networks*: 247-259. Dordrecht, Heidelberg, London, New York: Springer.

Dragomir C.S., Craifaleanu I.G., Dobre D., Georgescu E.S. (2016): An experimental investigation on the health monitoring of the new City Hall building in Bucharest based on real-time data transmission, 5th International Symposium on Life-Cycle Civil Engineering, 16-19 October 2016, At Delft, The Netherlands, Volume: CRC Press, Taylor and Francis Group, ISBN 9781138028470 - CAT# K26754 438 Pages.

Georgescu E.S., Borcia I.S., Praun I.C., Dragomir C.S. (2014): State of the art of structural health monitoring in seismic zones of Romania, Proceedings of MEMSCON 2014.

Georgescu E.S., Borcia I.S. (2005): Monitoring of buildings in seismic areas, *Journal of Constructions*, Year I, Issue 9, October 2005, ISSN: 1841-1290 (in Romanian).