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A HOLISTIC AND INTEGRATIVE CONCEPT FOR STRONG-MOTION RECORDS ON CONSTRUCTIONS OF THE URBAN-INCERC NATIONAL SEISMIC NETWORK

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Key words: Romanian seismic network, seismic instrumentation, seismic equipment, real-time data transmission.

Abstract: The main objective of the National Seismic Network for Constructions, operated by the National Institute for Research and Development in Constructions, Urban Planning and Spatial Territorial Development “URBAN-INCERC”, is the monitoring of situations generated by earthquakes or other dangerous sources of vibrations induced in constructions on the entire Romanian territory. The NIRD URBAN-INCERC seismic records obtained in-situ and on buildings were and are extremely important for designers, especially in 1977, 1986 and 1990. It is the largest network in Romania, consisting of some 60 digital acceleration recorders distributed in Bucharest and in the country. This network is strategic from the population safety point of view. Due to the specific seismic hazard and vulnerability, our country shall be in preparation for the impact of a possible earthquake, which cannot be predicted in time domain, but it is possible to occur anytime. To prevent and mitigate negative consequences of such an event, urgent actions are required to ensure structural safety. Given the facts, Romania is in a critical time on strategic options regarding the seismic risks.

Presently, a urgent necessity is the seismic network function in order to get as much as possible strong-motion data for advanced research and to understand why damages in buildings occurred. The next goal is to have more parametric and spectral data for engineering design, as well as to improve the zoning maps, having

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more stations at reduced distances. If possible, strong-motion micro-zonation data would explain some specific shaking differences, as a future option for local arrays.

The paper presents the necessity, means and requirements of achieving a holistic and integrative concept for the national seismic network of constructions, taking into account geological settings, environmental and local soil conditions on regional profiles, attenuation patterns, architectural and structural patterns, and number of seismic stations in specific seismic zones. Also, a case study of building seismic instrumentation in Bucharest according to the Romanian Seismic Design code, indicative P100-1:2013.

1. A seismic monitoring network of strong-motion records on constructions

The records in-situ and on buildings are extremely important for designers. The main objective of the *Seismic monitoring network of structures INCĐ URBAN-INCERC* refers to buildings monitoring and public works instrumentation or the monitoring of situations generated by other dangerous sources of vibrations induced in constructions on the entire Romanian territory. It is the largest network in Romania, consisting of 60 digital acceleration recorders distributed in Bucharest and in the country (Fig. 1).



Fig. 1. Distribution of GeSIG and Kinematics digital accelerographs in Bucharest & Distribution of GeSIG and Kinematics digital accelerographs in Romania

In order to achieve the instrumental recordings, the equipment integrated into the national seismic network includes the following types of digital functional stations: digital triaxial accelerometers ETNA, Kinematics; Stations K2 with 12 channels, Kinematics; digital accelerometers Basalt, Kinematics; Granite stations,

with 12 channels, Kinematics; accelerometers number GSR-24; digital accelerometers GeoSIG IA-1; digital accelerometers GSM 18 (Fig.2).



Fig. 2. Digital functional stations (GeoSIG GMS-18 station - left, ETNA - centre and Granite Kinematics Station - right)

Some possible schemes for the location of the triaxial sensors are shown (Fig.3). Recordings of dynamic parameters (structural spatial velocity in three main directions NS, EW and vertical Z), Fourier spectra, fundamental period of vibration (corresponding to values for the two transverse and longitudinally directions of a building) are obtained. Types of monitored buildings, with different heights and stiffness, and their equipments, are illustrated (Fig.4).

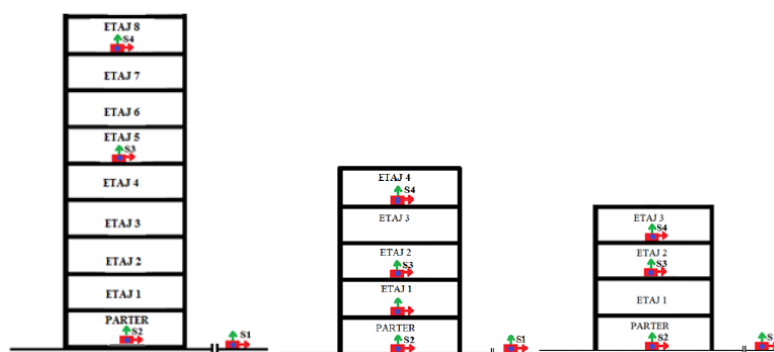


Fig. 3. Location scheme with 4 triaxial sensors



Figure 4. Types of monitored buildings

Resources and requirements of achieving a holistic and integrative concept for the national seismic network of constructions. A holistic and integrative concept for the national seismic network of constructions could be created taking into account the following aspects (Borcia and Georgescu, 2005; Borcia, 2006; Dragomir and Calin 2012; Dragomir et al, 2013; Dragomir, 2013; Dragomir et al, 2014; Călărășu and Dobrescu, 2009, 2011, 2013; Dobre et al, 2015):

related to building, monitoring and display the collected data in real time

- development and integration of new technologies for seismic instrumentation and monitoring, an integral structural assessment; in addition to monitoring and display the collected data in real time, also the opportunity for alert

through alarms, email or SMS, of a certain category of users about potential risks to buildings is aimed.

related to equipments

- purchase a greater number of seismic equipment for also a real-time data transmission;

related to materials

- development of tools to evaluate physicochemical and mechanical characteristics of materials;

related to seismic or ambiental vibrations

- study on determining the effects of vibration levels generated by seismic and non-seismic sources on structures;

related to types of soils

- experimental researches on the assessment of dynamic parameters for different types of Romanian soils, based on their real strength and deformation state, the evaluation of support elements in hazard, seismic risk and vulnerability analysis;

related to damages

- development of methods for damage detection and interpretation and surveying techniques;

related to modelling

- development and adaptation of theoretical models for simulation of structural and physical properties of buildings;

related to geological conditions

- more seismic stations for geological settings, environmental and local soil conditions on regional profiles;

related to attenuation

- more relevant, reliable attenuation patterns and laws;

related to stations

- more seismic stations for different architectural and structural patterns;

- an increased number of seismic stations in the seismic zones;

related to the concept of integrating the two systems, seismic early warning or alert and monitoring behaviour structures

- seismic warning systems or early warning can be used together with a monitoring system of building structures behaviour to improve pre-event and post-seismic seismic event forecasts;

related to the current trend in the estimation of seismic risk of buildings

- to create wireless sensor network capable of providing the necessary information for analysis and evaluation of post-seismic vulnerability of buildings;

related to the capabilities of a monitoring system

- must integrate also the needs of the owners of buildings so as to facilitate rapid assessment of the integrity of the building, data format shown to be in degrees of damage and to provide them in a relatively short time (a few minutes, if not seconds), if not in real time, in order to facilitate the decision making process having the necessary information;

related to integrated investigative methods of building performance after earthquakes

- analysis of the current international stage (US, Japan, China, Mexico, Turkey, Italy etc.) and in Romania demonstrates that there are premises that allow the continuation and expansion of advanced concerns in this field;

related to database

- development of databases and criteria for characterization of buildings etc.

The macroseismic analysis and the analysis of the instrumental data obtained from strong Vrancea earthquakes during 1977, 1986 and 1990 have shaken the faith of many specialists that initial Vrancea earthquakes causing relatively long period accelerographs records in many areas mainly due to local conditions (Georgescu et al, 2009). The local conditions have though a limited influence on the ground seismic motion and the differences in source mechanisms, that create directivity effects often differ depending on the spectral band, play a major influence in the ground seismic motion characteristics definition.

It is obvious the decisive contribution of the mechanism of the source and of propagation path on the spectral composition of ground seismic motion due to the geological conditions characterized by a gradual increase in wave propagation velocity S with increasing depth.

2. A case study of building seismic instrumentation in Bucharest, according to the Romanian seismic design code, indicative p100-1:2013.

A case study of instrumentation, reading and processing data according to Standard P100/2006 for Riverside Tower office building, located in Splaiul Independentei 291-293 sector 6, Bucharest, in case of earthquake, is presented and discussed. Some building details: Basement+ Groundfloor+15storeys + Technical Level, total built area 13,000 m², 66 parking places in 2 levels parking. Two triaxial EpiSensor sensors are placed on the fourth floor and on the terrace of the building (Fig. 5).

In terms of primary recorded magnitudes, by type of transducers, the accelerations of location points were recorded. Records processing was performed in the following steps:

- determining the maximum instantaneous acceleration and obtaining by calculating the velocities and displacements;
- frequency analysis of velocities and acceleration records.

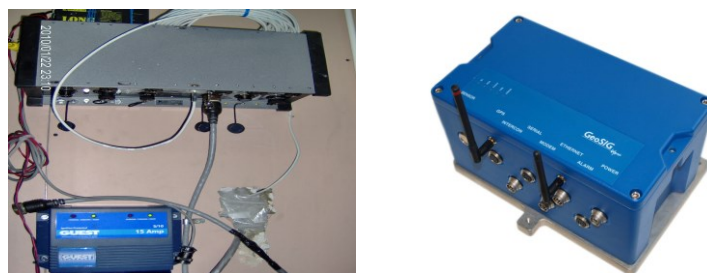


Fig. 5. GRANITE station installed on the terrace and the triaxial accelerometer GSM-18 is installed on the ground floor of the office building.

According to the data for both devices, the recorded seismic event from 22.11.2014 is the most important in the period March 2014-March 2015 ($M=5.7$). The two units have set the thresholds for triggering the acceleration 5cm/s^2 . The maximum value of recorded acceleration is $0.03g$ which represents a value of 30 cm/s^2 (on terrace level). Digital records of acceleration obtained using three triaxial sensors (2 EpiSensor and internal sensor GSM-18) were processed with GeoDAS and Strong Motion Analyst programs. The maximum instantaneous recorded accelerations and velocities are presented in Table 1 and the minimum values were considered $8.25.4\text{ mm/s}$.

Table 1. The maximum instantaneous accelerations, velocities and displacements recorded with accelerometers ETNA.

File name		PGA (cm/s^2)	PGV (cm/s)	PGD (cm)
GROUND FLOOR	TRG_100743_20141122_192356.ms	4.00		
LEVEL 4	20141122191510.dig1.ch1.KMI	12.00	6	1
TERRACE	20141122191510.dig1.ch1.KMI	30.00	13	2.2

In comparison, the PGA values obtained in earthquake 22.11.2014, in other sites within the National Seismic Network for Construction, are presented in Tab. 2.

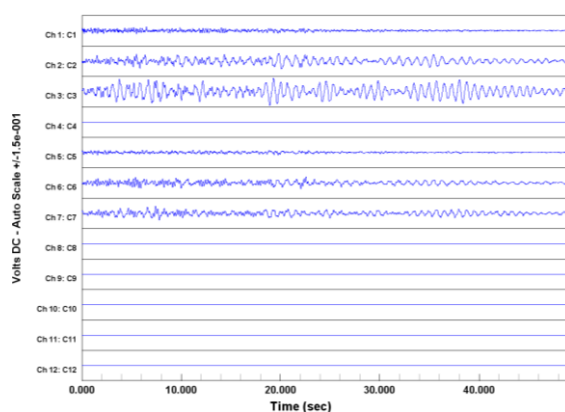
Table 2. Accelerations values obtained in the RNERC, Bucharest Branch INCERC

	Locality	Institution	Equipment	Acceleration (cm/s ²)	Acceleration (g)
1	Braila	ISU-PC (shelter)	GMS-18	121.5	0.1215
2	Bucuresti	INCERC (basement)	ETNA	3.2	0.0032
		Riverside Tower (ground floor)	GMS-18	4.0	0.0040
3	Buzau	ISU (warehouse)	ETNA	12.0	0.0120
4	Constanta	ISC (free field)	ETNA	9.4	0.0094
5	Galati	ISU (ground floor)	GMS-18	85.0	0.0850
6	Tulcea	ISU (ground floor)	ETNA	110.0	0.1100
7	Iasi	ITC(basement)	ETNA	18	0.0180
8	Iasi	INCERC(ground floor)	ETNA	26	0.0260
9	Bacau	ISU (ground floor)	ETNA	24	0.0240
10	Onesti	Library (basement)	GMS	20,78	0.0207

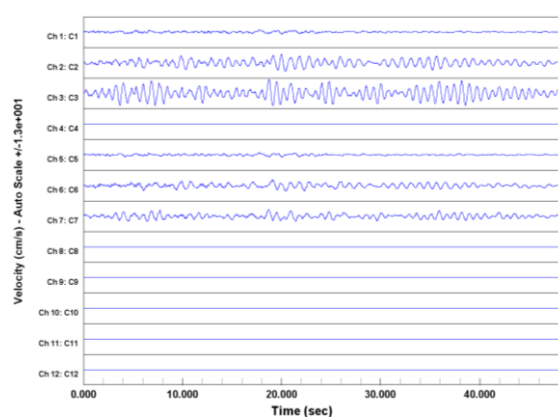
Some records obtained from the 22.11.2014 earthquake with two devices installed in the Riverside Tower office building

I. GRANITE station with two sensors installed at level 4 and on terrace

Station ID: SMARTS S/N 261 11/22/2014 19:15:10 (GMT)

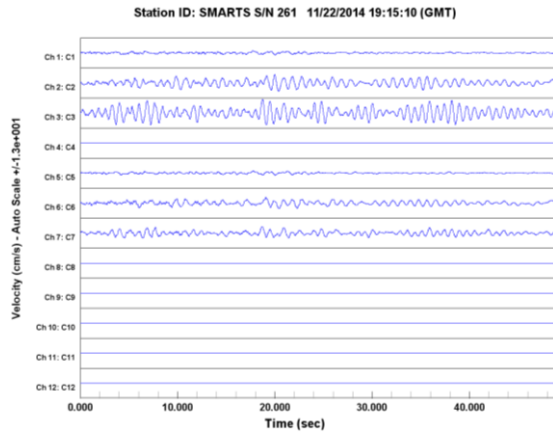


Station ID: SMARTS S/N 261 11/22/2014 19:15:10 (GMT)

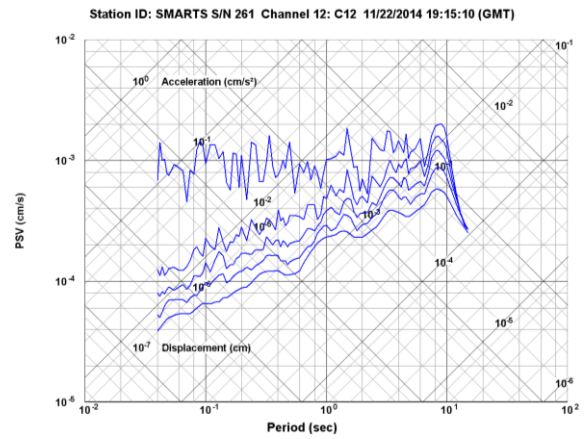


Acceleration time-history recorded by two triaxial sensors on the 3 orthogonal directions (X, Y and Z)

Velocity time-history recorded by two triaxial sensors on the 3 orthogonal directions (X, Y and Z)

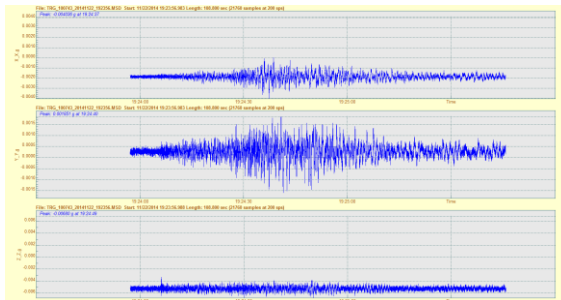


Displacement time-history recorded by two triaxial sensors on the 3 orthogonal directions (X, Y and Z)

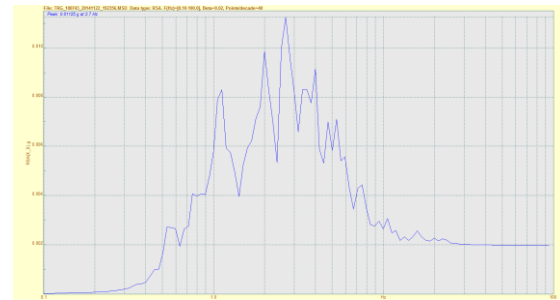


Tripartite representation of acceleration, velocity and displacement spectra

II. GMS-18 GeoSIG - triaxial accelerometer with internal digital sensor installed on the ground floor



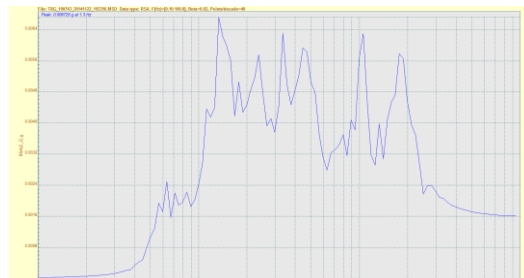
Accelerations recorded on the 3 orthogonal directions (X, Y and Z)



Acceleration response spectrum processed on X direction



Acceleration response spectrum processed on Y direction



Acceleration response spectrum processed on Z direction

Conclusions

This network is strategic from the population safety point of view. Due to the specific seismic hazard and vulnerability, our country shall be in preparation for the impact of a possible earthquake, which cannot be predicted in time domain, but it is possible to occur anytime. To prevent and mitigate negative consequences of such an event, urgent actions are required to ensure structural safety.

Presently, a urgent necessity is the seismic network functioning in order to get as much as possible strong-motion data for advanced research and to understand why damages in buildings occurred. 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. If possible, strong-motion micro-zonation data would explain some specific shaking differences, as a future option for local areas.

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