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REQUIRED EARLY WARNING SYSTEMS IN SUPPORT OF STRUCTURES BEHAVIOUR MONITORING SYSTEM

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Abstract

The Earthquake Early Warning Systems (EEWS) are currently in a number of countries with severe seismicity. They detect the initiation or development of earthquakes using the differences between the arrival of P and S waves and signals on-line of seismic sensors network and they emit a warning during the seismic wave will reach a site or another. This system can be used with a monitoring system of building structures behaviour "Structural Health Monitoring System" (SHMS) to improve pre-event and post-seismic event forecasts. EEWS can provide valuable information for civil structures and using information from both systems and SHMS and EEWS leading to a more accurate estimate of the loss and to an efficient safety alert. There are many countries where this correlation is permitted; in Romania also there are promising achievements in each of these areas. A system which can use all the capabilities and possibilities of these existing networks is shown.

***Key words**: earthquakes, behaviour monitoring, early warning.*

INTRODUCTION

Background on early warning systems. Seismic warning or alert systems are implemented currently in severe seismic countries such as Japan, Turkey, Italy, China etc. These systems detect the initiation or development of earthquakes using the differences between the arrival of P and S waves and signals on-line from seismic sensors network and emit a warning during the seismic wave will reach at a site or another. This type of system requires the existence of a network of seismic sensors located in seismically active areas, acquisition, processing and signal transmission, some interfaces of warning and generating alarms.

Background on real-time monitoring by seismic instrumentation and the need for documentation of buildings seismic response measurements. Monitoring by seismic instrumentation can contribute directly mainly to identify and determine the temporal variation of modal characteristics, Fourier amplitude spectra, damping coefficients etc. It also plays an important role in verifying the maximum level of relative displacement, the torsional response (especially for asymmetric structures), identifying needs for building repairs and strengthening as the effectiveness of preceding intervention measures, the displacement measurement for evaluation the drifts from strong earthquakes (Borcia and Georgescu, 2005; Borcia, 2006; Georgescu and Borcia, 2005). The need for documentation of measurements of seismic response of buildings is real, so the implementation of strategies dedicated to these activities should include resource allocation, as a national priority; development of criteria for selecting some representative buildings and specific objectives of measurements; stimulation of progress in investigating technologies; encourage owners to invest in seismic monitoring, by providing by structural engineers of products that homeowners be able to understand and use;

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plans and resources for data archiving and dissemination (Celebi et al., 2014).

MATERIALS AND METHODS

Rapid INFP alarm system in case of earthquake. Based on researches about 15 years, at the moment, in Romania, the National Institute for Earth Physics - INFP has installed an alarm system mainly to alert the important objectives in the area of Bucharest, Figure 1 (eg. Irradiator at the Institute of Atomic Physics at Magurele).

This early warning system was developed to provide a warning for 25 - 35 seconds for installations from Bucharest, in the event of earthquakes with magnitude greater than 6.5. INFP has developed a detection algorithm for calculating the Vrancea intermediate earth-quakes magnitude using strong motion data field, a rapid assessment and scaling relationship between maximum acceleration of P wave amplitude measured in the epicentral area and the largest ground motion recorded in Bucharest or in other cities in the affected area of Vrancea.

The system can be used to: (I) - alarm and blocking nuclear installations of national interest; (II) - blocking the gas supply valve for housing or industrial installations; (III) - walking slowing or stopping passenger and goods trains; (IV) - blocking the water supply valves for industrial installations; (V) - enabled rescue facilities; (VI) - enabled backup systems and data bank rescue operations for interest (banks, police etc.); (VII) - alerting hospital operating rooms and emergency generators start automatically etc. (Marmureanu et al., 2012; Bose et al., 2007).

Seismic Warning System (SAS) was developed in 1999 and the investment was made possible by funds from the company "FOTON 2000 SELF" Ltd., Figure 2.

The system was designed and implemented to transmit by radio-paging seismic alarm about earthquakes in epicentral area Vrancea in 25-30 seconds before reaching wave "S" (destructive) in Bucharest.

Seismic monitoring network of structures INCD URBAN-INCERC is oriented to buildings monitoring and public works instrumentation. Records on in-situ and on buildings were and are extremely important for designers. National Seismic Network INCERC is the largest network in Romania, consisting of approx. 60 digital accelerographs distributed in Bucharest and in the country (Figure 3 and Figure 4).

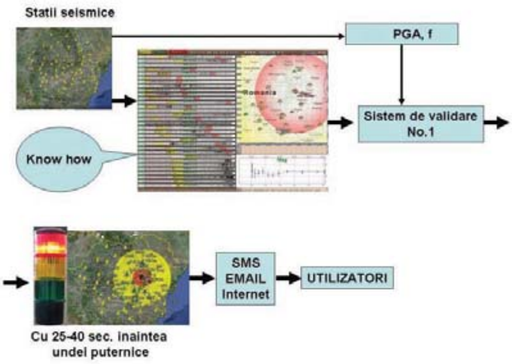

Figure 1. Rapid INFP alarm system in case of earthquake [http://ews.infp.ro/rews.php]

Figure 2. Seismic Warning System (SAS) [http://www.fotonsas.ro/]

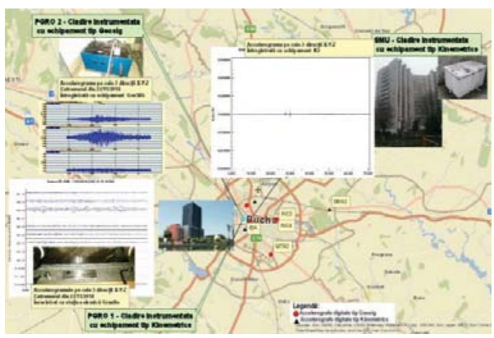

Figura 3. Distribution of Geosig and Kinemetrics digital accelerographs in Bucharest

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Figure 4. Distribution of Geosig and Kinematrics digital accelerographs in Romania

Method of seismic instrumentation. Possible schemes for the location of the triaxial sensors are shown in Figure 5 and 6. Recordings of dynamic parameters (structural spatial speed 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.

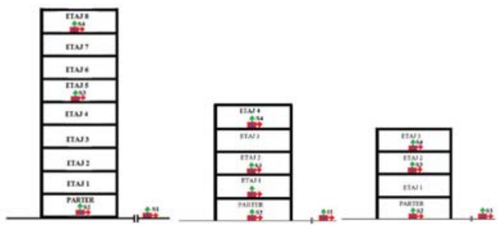

Figure 5. Location scheme with 4 triaxial sensors.

Combined method. Seismic warning systems or early warning "Earthquake Early Warning System" (EEWS) can be used together with a monitoring system of building structures behaviour "Structural Health Monitoring System" (SHMS) to improve pre-event and post-seismic seismic event forecasts (Figure 6). If it is a pre-seismic event forecast, EEW system information are used to determine the likelihood of some degree of damage to structures using a methodology for estimating the damage using the performance-based seismic engineering. These predictions can support those who make decisions on appropriate intervention enabled systems. Since the time between warning and recording earthquake is very short, probabilistic predictions must be readily determined and the decision is automatic for intervention actions.

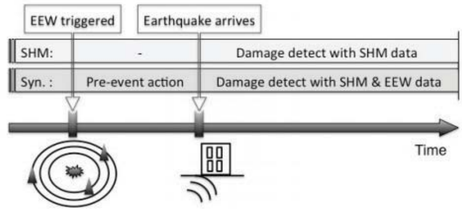

Figure 6. Combining the information received from the two systems (in time) [Wu and Beck, 2011]

In structural engineering software for SHM have developed or are in developing, with which to detect changes in the structural characteristics, changing local rigidities, evaluating the potential damage to the structure. Structural response received from the sensor network is used to determine the changed stiffness based on linear models/nonlinear, differences between modal parameters calculated for a finite element structural model and modal characteristics of dynamic tests using ambient vibrations. Accessing data from EW system by HM system can improve estimates related to failures and losses.

RESULTS AND DISCUSSIONS

Existing systems in which have been integrated early warnings or alert, and monitoring seismic behaviour of structures.

Japan - Real-time observation system for earthquake early warning and monitoring structures (Kuyuk and Motosaka, 2008, 2014). There are two complementary systems, Japan's national EEW system, which adopts the method of "network" and was inaugurated in 2007 by the Japanese Meteorological Agency (JMA), and seismic observation system in the Sendai area, based on the "front detection" which is one of observation in real time, not only seismic records (event mode, information before the arrival of seismic strong phase), but the response of buildings (normal mode provides real-time status of structural damage).

Ital y- Probabilistic Rapid Alert System and Evolution (Presto). An early warning procedure for predicting to regional scale, based on P waves arrive in an area with potential for damage and loss, was implemented in Probabilistic System Early Warning and Evolution, which is a portable platform developed by the Laboratory of RISSC Department of Physics of the University of Naples "Frederico II" (Picozzi et al., 2014). The procedure uses the characteristic period P-wave and peak displacement primary wave signal measured at each station P values are then compared with empirical regression defaults. A warning level at each station correlated with the expected level of local damage will get. Thus, integrating the parameters measured on-site stations (between P waves and movement characteristic peak) and estimate the regional settings (hypocenter), Presto can identify the affected area a few seconds after the onset of the event, with a good agreement with the instrumental intensity map produced later.

Turkey. The earthquake rapid response and early warning system in Istanbul (IRREW), designed and used by Univ. in Bogazici with 100 sensors record seismic motion in the metropolitan area that require fast data on damages, 10 seismic stations very close to the Marmara fault for data collection in the early warning system and 60 critical sensors on buildings (Erdik, 2006). After the onset an earthquake, each station will process the seismic movement to lead the spectral accelerations at certain times and send these parameters as SMS messages to the main data centre through available GSM network services.

China. The national project on seismic alert has been initiated and will be conducted by the Institute of Mechanical Engineering IEM-Harbin, belonging to the China Earthquake Administration - CEA, under the State Council, in the next 5 years it will cover approx. 50% of the territory, with 8878 stations. Several projects are being funded by the National Foundation for Natural Science of China, among which key project "Study of damage characteristics of strong seismic actions and seismic simulation field."

A proposed system by INCD URBAN-INCERC. The National Network for Earthquake Engineering - RNSC of INCD URBAN-INCERC provides data on seismic response of buildings and about structural vulnerability, Figure 3, and INFP monitors the seismological conditions and it began the implementation of a regional early warning system, Figure 1. The system which can use all the capabilities and possibilities of these networks is shown in Figure 7.

CONCLUSIONS

The current trend in the estimation of seismic risk of buildings is to create wireless sensor network capable of providing the necessary information for analysis and evaluation of post-seismic vulnerability of buildings. 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.

Also, *regarding the capabilities of a monitoring system,* they 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.

Regarding 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.

The concept of integrating the two systems, EEWS (seismic early warning or alert) and SHMS (monitoring behaviour structures) will use their basic characteristics and the clear possibility, already adopted in some countries, of a data correlation supplied after an earthquake. Although now there are many countries where this correlation is permitted, in Romania there are promising achievements in each of these areas.

In this context, the National Network for Earthquake Engineering - RNSC of INCD URBAN-INCERC provides data about seismic response and structural vulnerability of buildings and INFP monitors seismological part and began the implementation of a regional early warning system.

INCD URBAN-INCERC has demonstrated that based on records of response of buildings to moderate intensity Vrancea earthquake, some processing which contributes to the understanding of structural response (Dragomir et al, 2012, 2013; 2014), such as absolute acceleration response spectra (spectra floor), Fourier spectra amplitude and amplification functions were obtained.

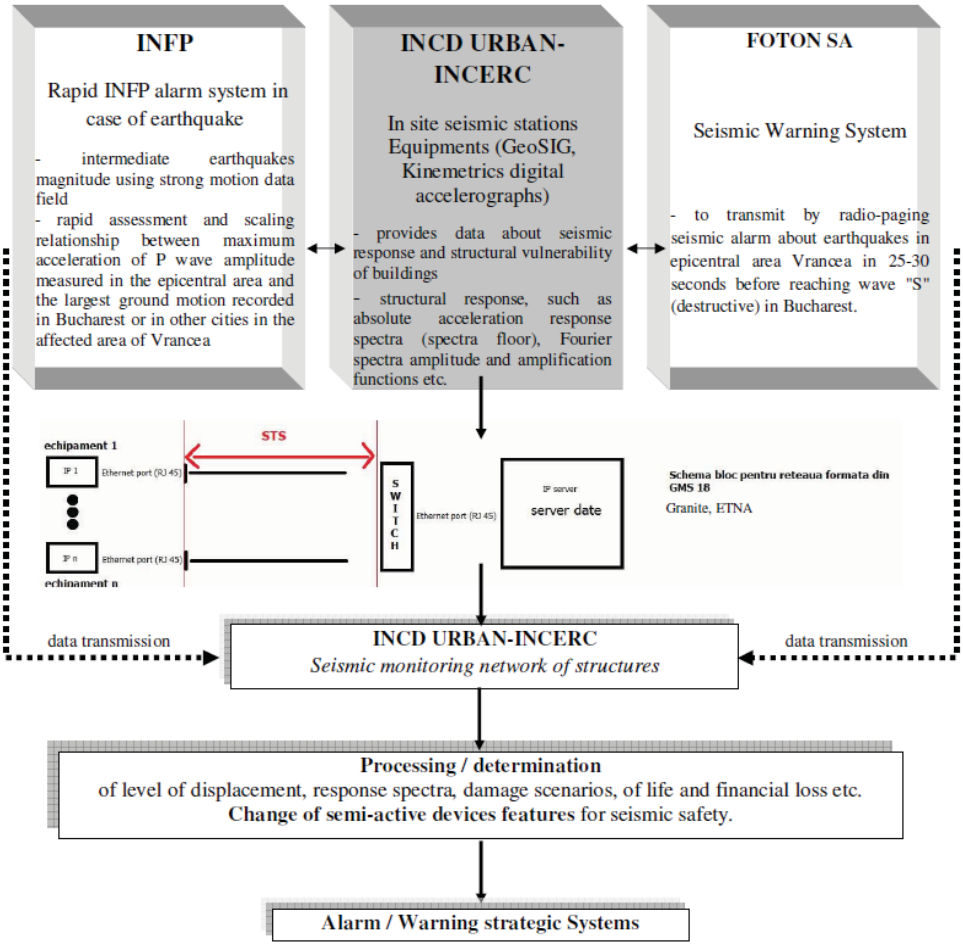

Figure 7. Seismic alert or early warning System and monitoring the behaviour of buildings

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