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METHODS OF SAFETY ASSESSMENT THROUGH ANALYTICAL AND EXPERIMENTAL APPROACHES

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Abstract

The paper is intended to present some aspects regarding the safety evaluation methods by determining those defining characteristics of a structural system (behaviour in time through dynamic characteristics evolution). This assessment should first be initiated in the case of buildings with essential functions and which could pose a major threat to public safety in case of collapse or serious damage. Determining, using intelligent wireless sensor networks, used within of a real-time data transmissions system, of some accelerograph data obtained from earthquakes with significant magnitude, will lead to an image of the spatial distribution of peak ground acceleration (PGA). Obtaining additional data over time will highlight some conclusions about acceleration values and directivity of seismic waves in the territory. On the other hand, the determination of the dynamic characteristics of structural systems by non-invasive and non-destructive instrumental measurements, under normal micro-seismic agitation, offers the possibility of obtaining important data in the structural safety assessment process after a major earthquake. Correlation of structural dynamic information, determined in situ and by analytical approaches, is a necessary step in the continuous process of risk exposure in an area with disaster potential. Data about a few study cases are presented.

Key words: *experimental investigation, PGA distribution, structural frequencies.*

INTRODUCTION

The paper is intended to present some aspects regarding the safety evaluation methods by determining those defining characteristics of a structural system (behaviour in time through dynamic characteristics evolution).
Instrumental post-earthquake and eventual post-consolidation data are not sufficient unless there are pre-earthquake data. In this sense, it is possible to have pre-earthquake control data by determining the natural periods of the structure, in the current state and after an earthquake (moderate or severe). Thus, there will be a dynamic database with predetermined pre and postseismic values.
This assessment should first be initiated in the case of buildings with essential functions and which could pose a major threat to public safety in case of their collapse or serious damage.
Immediately after a strong future earthquake, a public institution will be interested in determining as soon as possible the „health" of its headquarters and other buildings, especially those that are needed to carry out its tasks of emergency situations or orders to customers: the headquarters of the county emergency inspectorates; buildings belonging to universities/high schools/schools; hotels; high buildings falling within the requirement for seismic instrumentation according to Annex A4 of the seismic design Code P100-1/2013.

MATERIALS AND METHODS

A real-time data transmissions system. The seismic stations of this system are placed in some ground floor-buildings type, assimilated with the free-field, or in buildings with 1-3 levels. First application of the system is related to the accelerographic data, obtained from earthquakes with significant magnitude, or from ambient vibrations, which will lead to an image of the spatial distribution of peak ground acceleration (PGA).
Obtaining additional data over time will highlight some conclusions about acceleration

values and directivity of seismic waves in the territory. From data obtained within the URBAN-INCERC network (through the real-time data transmission system), during M>5 Vrancea seismic events, that occurred in 2016 and 2017, the spatial distribution of the peak ground accelerations confirms certain typical patterns, as the NE-SW general directivity and the PGA amplification at large distances from the epicentre area, observed also in previous larger-magnitude events.

Basic signal processing within the system. The procedure used to reduce leakage of a measured signal, when the measuring time is not a integer multiple of the signal period, this meaning those non-zero values at frequencies other than that of interest, is the signal transformation by the introduction of a window function, depending on the analysed signal type. Also, some filters are applied, as low-pass, high-pass etc.

Signal analysis. The signal analysis and determination of the dynamic characteristics of structural systems for damage detection use only the output signals. Depending of the type of input (ambient excitation or severe earthquake), generally difficult to be measured, with the global [M], [C] and [K] matrices obtained from the geometry and material properties for the dynamic system, the output is measured and some frequency/time domain approaches are applied in order to obtain the modal parameters which are needed to the damage estimation (damage is frequently associated with inter-story drift and behaviour of structural and non-structural components). It is assumed that mass does not change; there is a change in stiffness (also in damping). In the case of the ambient excitation, the response is considered in the linear range, in large frequency band-width and with low amplitude, and the damping takes very low values.

On the other hand, the dynamic characteristics of structural systems determined by non-invasive and non-destructive instrumental measurements, under normal micro-seismic agitation, offers the possibility of obtaining important data about the behaviour of the building in the structural safety assessment process after a major earthquake (Dobre and Dragomir, 2017).

Stiffness loss. In one dynamic degree of freedom (or all, but matriceal), the damage (stiffness loss) is calculated with a simplified formula:

$$\Delta K = \frac{K_{init} - K_{current}}{K_{init}}, \ldots\ldots\ldots\ldots\ldots\ldots \qquad (1)$$

where:

K_{init}= the stiffness before a major event, $K_{current}$= the stiffness after a major event.

After simple processing,

$$\Delta K = 1 - \left(\frac{\omega_{current}}{\omega_{init}}\right)^2 \qquad (2)$$

The method of getting the dynamic characteristics of structural systems and the damage/stiffness loss is presented in Figure 1.

Study cases. Data about a few study cases are presented:

- Recorded data in 2017 at the Building A of the Parhon Institute, Bucharest (built in 1928) (Figure 2).

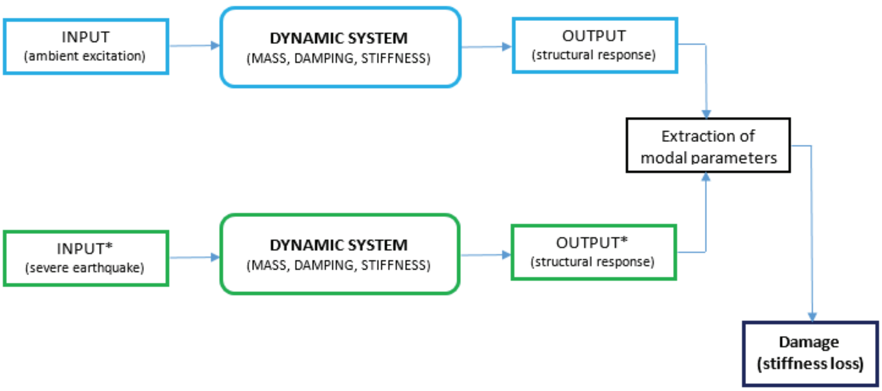

Figure 1. Method of damage detection using ambient vibration signals

- Recorded data in 2016 at the Building of the Hospital N. Oblu, Iasi (built in 1972), (Figure 3).

- Recorded data in 2016 at the Building of the General Inspectorate for Emergency Situations (IGSU), Bucharest (built in 1968) (Figure 4).

Figure 2. Vertical layout of sensors (ground floor, level 2, terrace), H=12.39 m

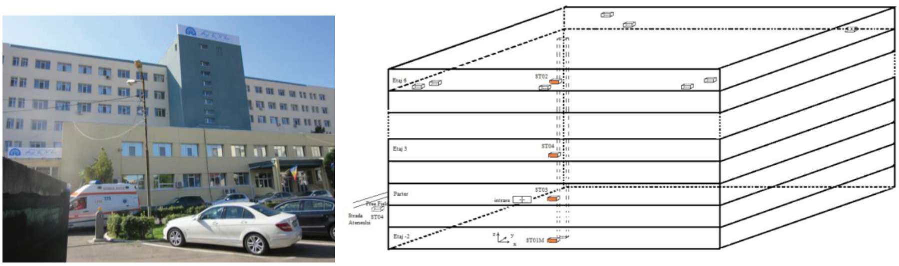

Figure 3.Vertical layout of sensors (basement 2, ground floor, level 3, level 6), H=28.9 m

Figure 4.Vertical layout of sensors GMS Plus (Building A - ground floor, level 3, level 5, terrace, and Building B - ground floor, level 3, level 5 and level 6), H=28 m/30.1 m

RESULTS AND DISCUSSIONS

Correlation of structural dynamic information, determined in situ and by analytical approaches, is a necessary step in the continuous process of risk exposure in an area with disaster potential, (Tables 1, 2 and 3 and Figures 5, 6, 7 and 8).

The dynamic characteristics of building vibration can be obtained also from a simplified formula, according to the Code P100-2013: $T_1=C_tH^{3/4}$, where C_t=0.075 for spatial frames from reinforced concrete or steel/ C_t=0.05 for other structural systems; H = the height of building.

Table 1. Vibration frequencies, Parhon Institute

from seismic/microseismic/ambiental records	f_x= 3.5...5.6 Hz f_y= 2.0...3.8 Hz

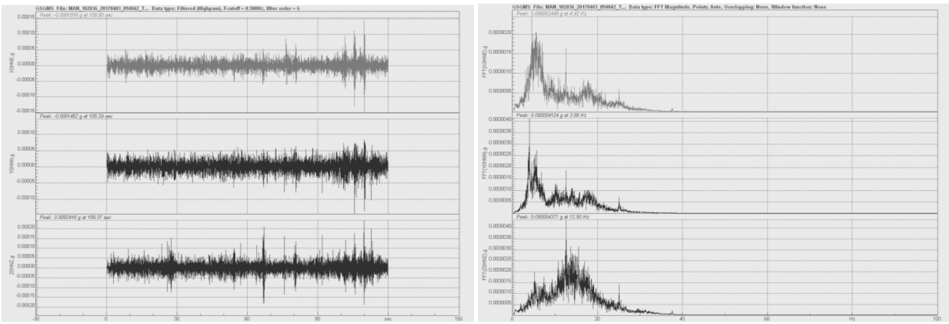

Figure 5. Accelerogram processing and Fourier spectra, level 2, T_1=0.3s.
According to the Code P100-2013: T_1=0.3s (C_t=0.05)

Table 2. Vibration frequencies, Hospital N. Oblu

from seismic/microseismic/ambiental records	f_x= 1.88/1.93 Hz f_y= 2.00/1.98 Hz

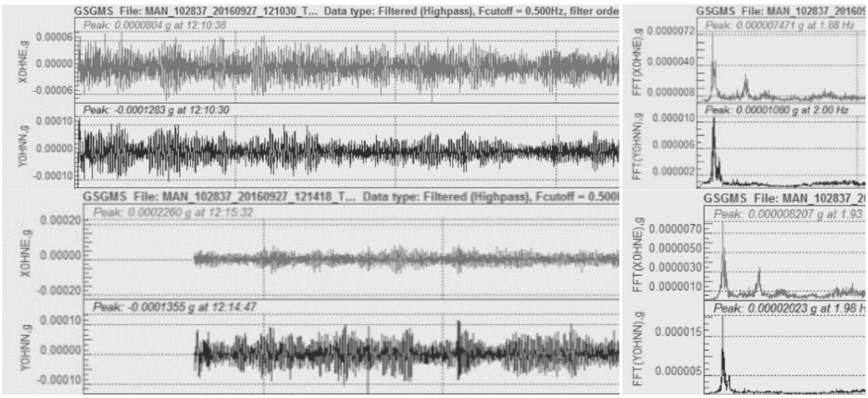

Figure 6. Accelerogram processing and Fourier spectra, level 6, T_1=0.53s;
according to the Code P100-2013, T_1=0.62s, (C_t=0.05)

Table 3. Vibration frequencies, IGSU Bucharest

	Building A	Building B
from seismic/microseismic/ambiental records	f_x = 1.56…1.64Hz f_y = 1.49…1.56Hz	f_x = 1.56…1.71Hz fy = 1.50…1.54Hz

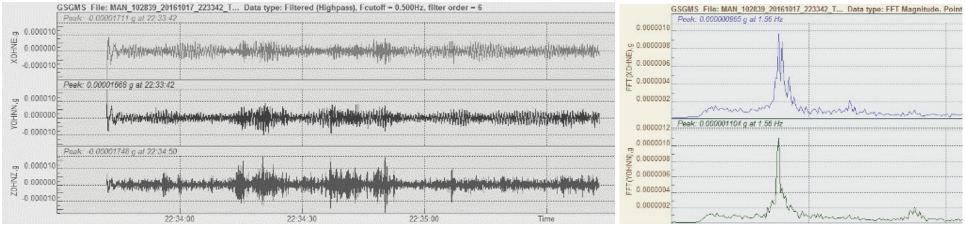

Figure 7. Accelerogram processing and Fourier spectra, Building A, T_1=0.60s;
according to the Code P100-2013, T_1=0.60 s (C_t=0.05)

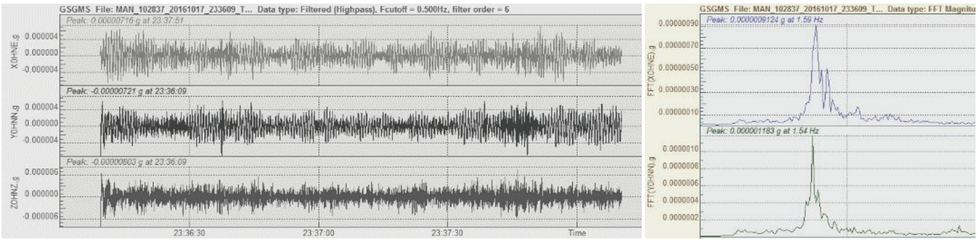

Figure 8. Accelerogram processing and Fourier spectra, Building B, T_1=0.64s;
according to the Code P100-2013, T_1=0.60 s (C_t=0.05)

CONCLUSIONS

Vibration-based structural health monitoring is an approached widely used due to its 'output only' nature. The core of this method is to detect the changes of the dynamic features extracted from the structural response - the variations of natural frequencies.

Immediately after a strong future earthquake, a public institution as a hospital will be interested in determining as soon as possible the structural health of its buildings and in this respect a „zero reading" of the dynamic structural features is important (Dragomir et al., 2017).

Determining the level of vibrations in a structural system is used also for choosing the procedure or the mechanism of mitigates this type of response (the comparison among passive, active and semi-active control systems) (Pastia et al., 2016).

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