Variation of vibration period of a RC building during the Pollino seismic swarm

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OBJECTIVE

During the seismic sequence still on-going in the Pollino area, Southern Italy, we monitored the reinforced concrete school in Rotonda, a regular, three-stories reinforced concrete frame, floors in bearing precast slabs, internal walls in concrete bocks and external infills in precast slabs.

During the sequence the school suffered no damage.

The real-time monitoring of the school proved to be important for two reasons:

- The large range of magnitudes and recorded PGAs allowed to study the non-stationarity of the frequency response both inter- and intra-events;

- The experiment also allowed to envisage the use of simple, real-time monitoring system as a possible tool to provide information about the state of damage and the usability of a school.
1a) **Variation in elastic domain**

Moderate earthquake (PGA between 0.1 and 1m/s²), still in the elastic domain (Hans et al. 2005; Michel et al. 2008, 2010). The opening of cracks induces non-linearities, that produce a frequency decrease reaching **35%**. (Dunand et al. 2006)

\[ \Delta f_1 = \frac{f_{\text{iniz}} - f_{\text{min}}}{f_{\text{iniz}}} \]

2b) **Frequency decrement due to damage**


It seems that a value of **60%** drop in frequency is a limit before the collapse according to data compiled by Calvi et al. (2006).

\[ \Delta f_2 = \frac{f_{\text{iniz}} - f_{\text{fin}}}{f_{\text{iniz}}} \]
Temporary and Permanent Period Elongation

DOPO IL 31 OTTOBRE
EMS=2

DOPO IL 1° NOVEMBRE
EMS=4

Δf1=24% permanent
Δf2=48% temporary

Mucciarelli et al., BSSA, 2004
February 09, 1971 $M_I = 6.6$ San Fernando Earthquake normalized recording at the roof of the Millikan Library on CalTech campus (California) in E direction

*Michel and Gueguen, Structural Health Monitoring, 2009*
The effect of damage: *permanent period elongation*

Vidal et al., BEE, 2013

Ditommaso et al., NHESS, 2013
2nd floor: G3, ETNA
1° floor: G4
Ground floor: G5

G3, G4 and G5 = GeoSIG accelerometers
The monitoring started in September 2011 with a single station atop the building, while after the MI=5 event occurred in October 2012 a more complete system was installed with a GeoSIG accelerometer at each floor and real-time transmission of the data streaming with acquisition at the Istituto Nazionale di Oceanografia e Geofisica Sperimentale (OGS).
Recorded Earthquakes

- foreshocks
- aftershocks
- mainshock
Variation in elastic domain: temporary period elongation

**F_HVSR_noise_transversal**

5.5 Hz

**Transversal direction**

40%

Graph showing seismic data with different magnitudes and periods.
Variation in elastic domain: temporary period elongation

F_HVSR_noise_longitudinal

6 Hz
**TRANSVERSAL**

**LONGITUDINAL**
S-transform: Mainshock M=5.0

TRANSVERSAL

Frequency (Hz)

Δf1 = 48%

Acceleration (g)

Time (s)
S-transform: Mainshock $M=5.0$

LONGITUDINAL

Frequency (Hz)

$\Delta f_1 = 44\%$
Structural health monitoring: ETNA vs GeoSIG accelerometers

Transversal direction

Period (sec)

Sa (g)

GeoSIG

ETNA

FORE1 MI=3.0
FORE2 MI=3.6
FORE3 MI=3.3
FORE4 MI=3.3
FORE5 MI=3.5
FORE6 MI=3.0
Main shock MI=5.0
AFTER1 MI=3.4
AFTER2 MI=3.4
AFTER3 MI=3.2
AFTER4 MI=3.1
AFTER5 MI=3.2
AFTER6 MI=3.7
AFTER7 MI=3.3
✓ The absence of permanent period elongation is more important than the amplitude of temporary elongation as an indicator of the absence of damage;

✓ The real-time building monitoring proved to be an effective tool to help deciding about the usability of the building itself;

✓ The MEMS sensors prove to be reliable above 2mg.