INTRODUCTION. Catania is one of the Italian cities having a high seismic hazard. Several studies (Azzaro and Barbano, 2000; Panzera et al., 2011) show that the seismic history of this area is characterized by large events (1169, 1542, 1693) having a moment magnitude ranging from 6.2 and to 7.3 (Rovida et al., 2016), and enhancement of seismic effects was usually observed as a consequence of local geo-lithologic features. This area was therefore selected to conduct a field experiment aiming to estimate the buildings fundamental period, taking into account their technical features.

Simplified methods usually estimate the fundamental frequency of a building by postulating it as a function of its geometry and its total height. In recent years, experimental techniques using either earthquake or ambient noise signals have been proposed to evaluate the dynamic parameters of buildings (Parolai et al., 2005; Gallipoli et al., 2008). In the urban area of Catania, a preliminary evaluation of the vulnerability and a few estimates of the fundamental period of buildings, were carried out by Faccioli et al. (1999), Panzera et al. (2013) and Imposa et al. (2017).

In this frame, the University of Catania has promoted and supported surveys aiming at evaluating the dynamic features of the buildings making up its assets (Fig. 1). Therefore, contributing to evaluate and reduce the vulnerability of all the University building heritage.

Most of the investigated buildings are erected in the Catania downtown, therefore emphasizing their structural complexity (masonry building with the presence of reinforced concrete elements), irregular plan shape and the presence of adjacent structures. The present study refers to the suitability of ambient noise records, processed through the standard spectral noise ratio (SSNR) methods, to define the dynamic properties of masonry buildings in such complex situation. Although, such a technique was already successfully used by several authors in many areas (Gallipoli et al., 2008) and these kind of studies are important in investigating possible soil-structure resonance effects, some attention should be paid in the interpretation of results.
Methodology. Usually the most vulnerable area of a city is its downtown where several historic buildings are erected. The cultural heritage safeguarding is becoming in recent time particularly important due to its economic and social significance. These valuable constructions often undergo to a reduced structural capacity due to deterioration phenomena and damages suffered in the past. Geophysical surveys are normally adopted as tool for cultural heritages restoration and protection plans (e.g. Imposa et al., 2014; Imposa and Grassi, 2015). Moreover, cultural heritage buildings were typically built without considering seismic action and therefore they are potentially susceptible to earthquake damage. It is, indeed, well known that the level of building damage and its distribution during an earthquake is due to the combined effect of the local site response, based on subsurface ground conditions, and the dynamic features of the structure itself.

The dynamic properties of a building is usually described through its natural frequency and
the damping ratio (\(\zeta\)). The latter parameter represents the energy loss of an oscillating system that can be either internal (material damping) or due to another system (radiated damping). The damping ratio is important in seismic design since it allows to evaluate the ability of a structure to dissipate the vibration energy during an earthquake. Such energy causes a structure to have the highest amplitude of response at its fundamental frequency, which depends on the structure’s mass and stiffness. Therefore, the damping level, as well as the knowledge of the fundamental period \((T)\) of the building are particularly important for estimating the seismic base shear force \(F\) in designing earthquake resistant structures.

The seismic performance of a building obviously depends on the progression of the frequencies along the input time-history, nevertheless the knowledge of its fundamental frequency at low amplitude values and the associated damping are of primary importance to characterize the initial seismic behavior of a structure. These parameters can usually be obtained either through numerical modelling or experimental monitoring of the building using different input motions.

In the present study, the standard noise spectral ratio (SSNR) and horizontal to vertical spectral ratio (HVSR) techniques were used to identify the building and site fundamental frequencies. Measurements are going to be performed in 70 buildings distinguished according to their construction typology into masonry buildings (MA) and reinforced concrete (RC) buildings. Ambient noise was recorded using a three-component velocimeter, sampling the signal at a frequency of 128 Hz. In each building, 20 minutes length ambient noise samples were recorded both at the top and at the ground floor. According to the guidelines suggested by the European project Site Effects assessment using AMbient Excitations (SESAME, 2004), time windows of 20 s were considered, selecting the most stationary parts and not including transients associated to very close sources. Fourier spectra were calculated in the frequency band 0.5-20 Hz and smoothed using a triangular average on frequency intervals of \(\pm 10\%\) of the central frequency. In Fig. 2 example of results, obtained for measurements performed in the area of “Palazzo CLMA-COF” (Uffici in Fig. 1) and “Palazzo Ingrassia” (comparto Benedettini in Fig. 1) are shown. As concern the measurement performed inside the buildings to observe the influence of the geometry, the two main axes of sensors are oriented as coincident with the main directions of the building (NS \(\equiv\) transverse; EW \(\equiv\) longitudinal) in order to better highlight their respective contribution. The spectral ratio peak having the highest amplitude in the SSNR was considered as representing the building fundamental period (Fig. 2).

Fig. 2 - Example of SSNR graphs concerning the ambient noise measurements performed at the different floors of “Palazzo CLMA-COF” (upper panels) and “Palazzo Ingrassia” (lower panels).
Damping ratios were computed using the Random Decrement technique toolbox implemented in Geopsy (Fig. 3). This technique is based on the assumption that at each time step, the recorded signal is the sum of a random signal and the impulse response function of the study-system. Stacking many time-windows with the same initial condition implies the enhancing of the impulse response function component with respect to the zero-mean random part. The algorithm selects all the windows of the given length starting with a 0 amplitude and a positive derivative and averages them. Then, the impulse response function is fitted by an exponentially decreasing sine function (starting at 0) depending on an amplitude $\alpha$, the resonance frequency $f = \omega / 2\pi$ and the damping ratio $\xi$ (see for details: http://www.geopsy.org/).

![Examples of damping graphs obtained from measurements performed, for the NS and EW components, at the recording sites located in the “Palazzo CLMA-COF” (upper panels) and “Palazzo Ingrassia” (lower panels).](image)

**Results and concluding remarks.** In the studied buildings, ambient noise was recorded at each floor locating the sensors both at their center of mass and their edges. This settlement allowed us to point out the potential existence of complex dynamic behaviour of the investigated structures. Going into more details, such complex behavior is often observed in the buildings erected in downtown area where MA edifices, being adjacent, interact each other therefore showing the presence of several SSNR peaks (e.g. Palazzo CLMA-COF in Fig. 2). This complex behavior can also be ascribed to the influence of new elements, such as floor tiling, floating floors, piping, out-of-plane movements of detached walls and stairwells detached from the frame of the building, added across different periods in time. Conversely, isolated buildings having a regular plant (e.g. Palazzo Ingrassia in Fig. 2) are characterized by the presence of a dominant single SSNR peak. As concerns the damping values, although they are obtained through a weak motion input (ambient noise), they can achieve significant information. Results set indeed into evidence a link with the soil foundation and the building geometry. In our study, it appears in particular evident a variability linked to the different rigidity of the investigated structures, as a function of the longitudinal or transversal orientation of the structural elements. Moreover, the comparison between the buildings and the site frequencies, achieved through HVSR, allowed us to put into evidence the potential existence of site-to-structure resonance effects.
References


Imposa S., Grassi S.; 2015: Georadar survey inside the Santa Maria Maggiore Church of Ispica (Sicily-Italy). Environmental Earth Sciences, 73, 1939-1949, doi: 10.1007/s12665-014-3542-9


