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LECCE

22-24 novembre 2016

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EVALUATION OF THE DYNAMICAL FEATURES OF THE CATANIA UNIVERSITY BUILDING HERITAGE

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Introduction. The level of building damage and its distribution during an earthquake is due to the combined effect of local site response, based on subsurface ground conditions, and the dynamic features of the structures. The fundamental vibration periods of buildings are in particular important for determining their seismic performance. The engineering practice usually evaluate such features through empirical relationships, that estimate the building resonant frequency as a function of either the height or the number of floors, or through numerical modeling (Messele and Tadese, 2002; Gallipoli *et al.*, 2009; Panzera *et al.*, 2013). However, the discrepancy between the actual performance of a structure and the expected values can sometimes be significant, so that only the acquisition of experimental data allows us to appreciate its real dynamic behavior. Performing such investigations is particular important in earthquake prone areas like Catania and have primarily to concern the edifices of significant public interest such as schools and hospitals.

Catania is among cities in Italy having a high seismic hazard (Panzera *et al.*, 2011a, 2011b) and its seismic history is characterized by large events (1169, 1542, 1693) having a moment magnitude ranging from 6.2 and to 7.3 (Working Group CPTI, 2004). Its geo-lithologic features contribute also to the enhancement of seismic effects as observed in several studies (Faccioli and Pessina 2000; Panzera *et al.*, 2011, 2015), being the result of a complex setting with lateral heterogeneities at a local scale, due to the presence of volcanic and sedimentary units (Monaco *et al.*, 2000). In this frame, following the suggestions of the in effect regulations, the University of Catania has promoted and supported surveys aiming at evaluate the dynamic features of the buildings making up its assets. Therefore contributing to evaluate and reduce the vulnerability of all the University building heritage. Present study illustrate the example of investigations performed in the "Palazzo Boscarino", where the Department of Juridical Sciences is located (Figs. 1a and 1b).

Methodology. Simplified methods usually estimate the fundamental frequency of a building by postulating it as a function of its geometry and of 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). The dynamic properties of an edifice are usually described through its natural frequency and the damping ratio (ζ). 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

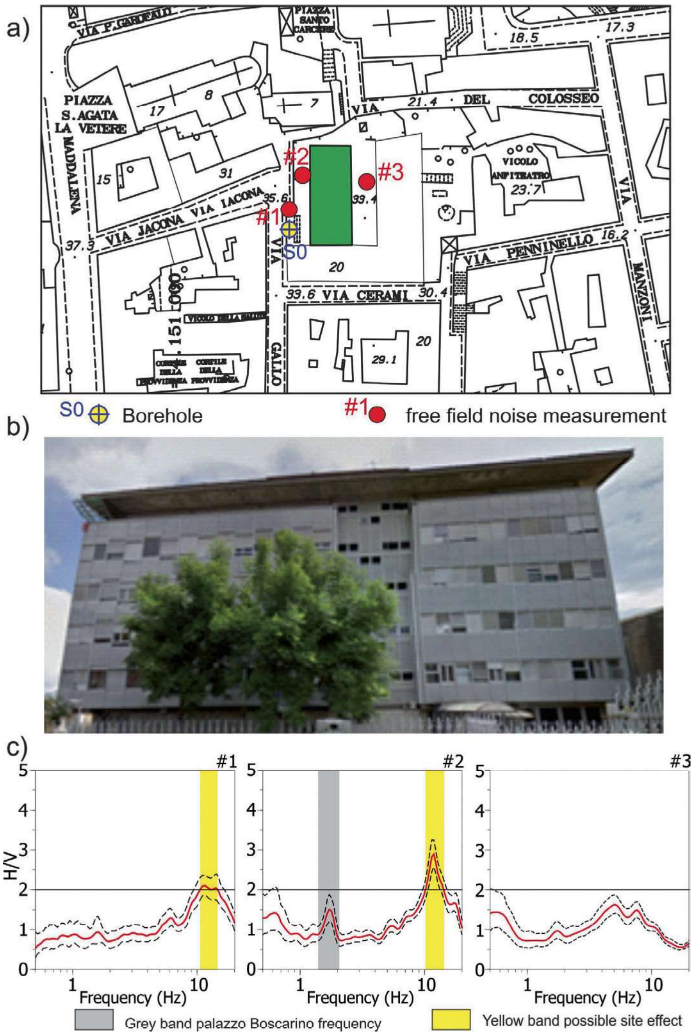

Fig. 1 – Location of Palazzo Boscarino and free field noise measurement sites (a); View of the building (b); H/V spectral ratios obtained at the free field recording sites #1, #2, #3.

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. Following the Eurocode8 (2003), F can be expressed as: $F = Sa\ (T;\ \zeta \bullet m \bullet \lambda$ where $Sa\ (T;\ \zeta)$ is the ordinate of the target spectrum at period T and damping ζ, m is the total mass of the building above the foundation or above the top of a rigid basement and λ is a correction factor. The $Sa\ (T;\ \zeta)$ is evaluated considering the local geological features, which influence the site response in term of amplification of the ground motion, as the seismic input travels from the bedrock to the overlying soil deposits.

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 behaviour of a structure. These parameters can usually be obtained either through numerical modelling or experimental monitoring of the edifice using different input motions.

In the present study, the horizontal to vertical noise ratio (HVNR) and the standard noise spectral ratio (SSNR) techniques were used to identify site and the building fundamental frequencies respectively. Measurements are planned to be performed in 70 buildings distinguished according to their construction typology in masonry buildings (MA) and reinforced concrete (RC) edifices. Ambient noise was recorded using a three-component velocimeter (Tromino) sampling the signal at a frequency of 128 Hz. In each building, 20 minutes length of ambient noise 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 part 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 ± 10% of the central frequency. In Figure 1b results obtained for *free field* HVNR measurements in the area of "Palazzo Boscarino", 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 ≡ T ≡ transverse ≡ minor axis; EW ≡ L ≡ longitudinal ≡ major axis) in order to better highlight their respective contribution (Fig. 2a). As fundamental period for each building we considered the peak with the higher amplitude in SSNR (Fig. 2b).

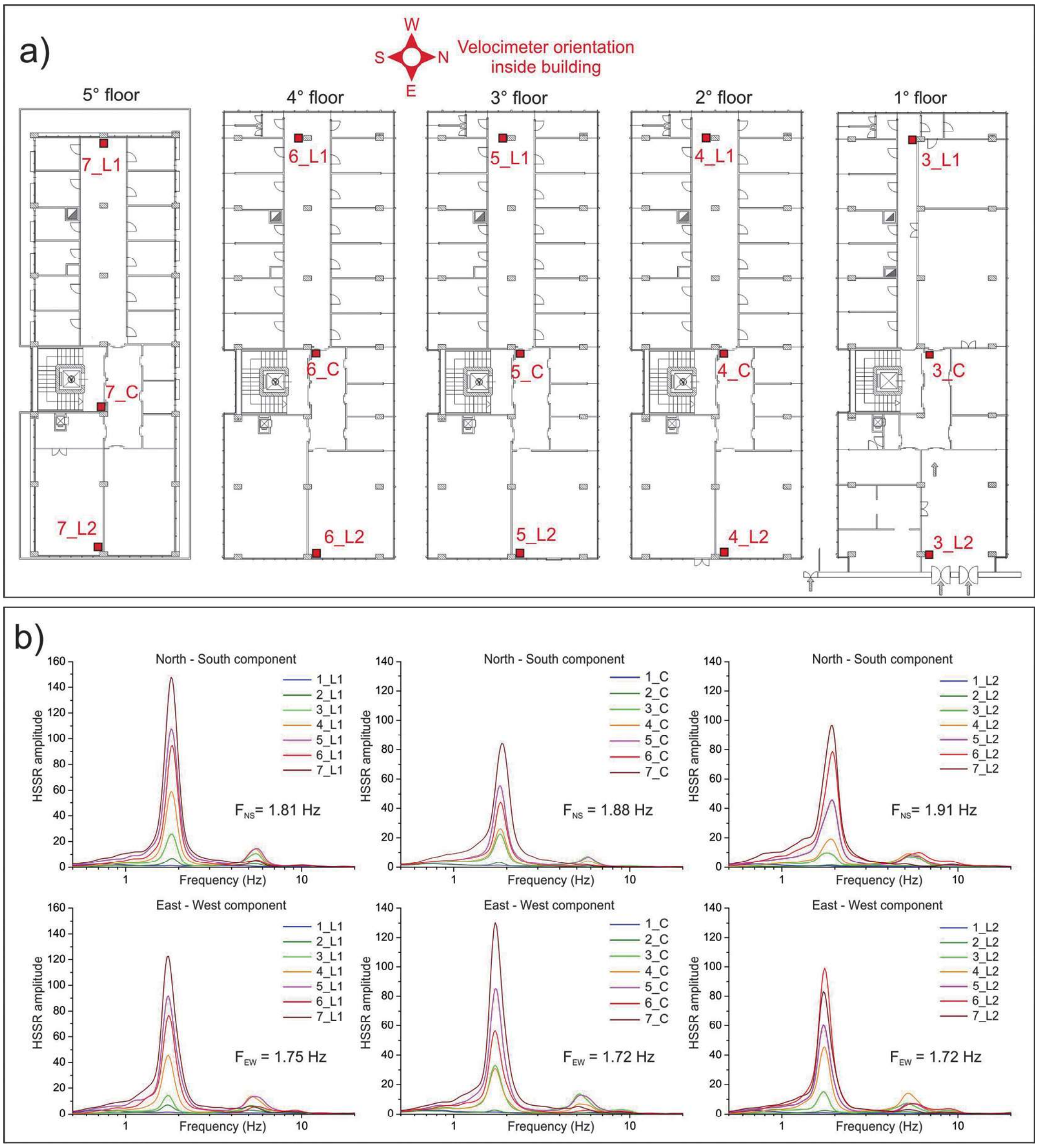

Fig. 2 – a) Positions of the ambient noise recording sites at different floors; C indicates the measurements performed in central part of each floor. L1 and L2 indicate the two opposite boundaries of the building respectively. b) HSSR graphs concerning the ambient noise measurements performed at the different floors of Palazzo Boscarino.

In addition to the fundamental period, the damping ratio was computed as well, using the Random Decrement technique toolbox implemented in Geopsy (Fig. 3). The Random Decrement technique is based on the assumption that at each time step, the 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 imply 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 α, the resonance frequency $f=\omega/2\pi$ and the damping ratio ξ (see for details: http://www.geopsy.org/).

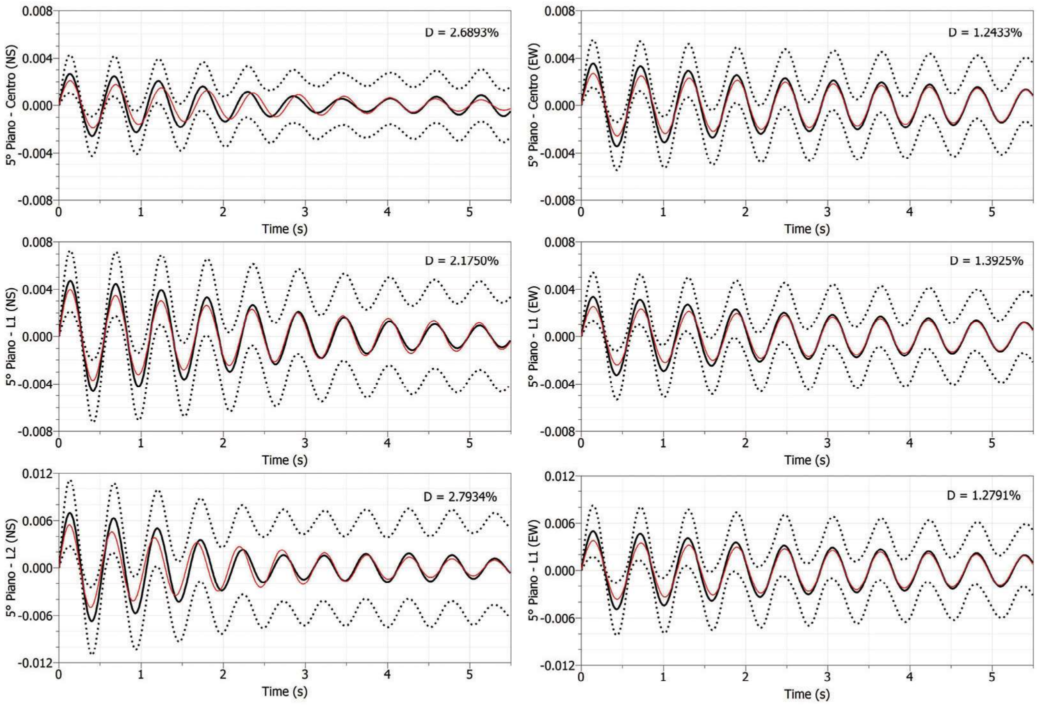

Fig. 3 – Examples of damping graphs obtained from measurements performed, for the NS and EW components, at the recording sites located at 5th floor of the building.

Results and concluding remarks. The present study aims at evaluating the dynamic properties of Palazzo Boscarino. It was taken into account as a first example of the complete amount of surveys planned for the evaluation of the Catania University buildings asset vulnerability. These studies are quite important in investigating possible soil-to-structure resonance effects that can arise when the fundamental frequency of a building shares the same range as that of the site.

The investigated building is the location of to the Department of Juridical Sciences and it shows a rectangular shape and it is formed by seven floors including both the ground and the underground floors. Its longitudinal section is NS oriented and it is erected on thin detritic layers and volcanics. The HSSR results point out that the fundamental frequency of the building is about 1.8 Hz. Inspection of the HSSR graphs, obtained from the measurements performed in the third to fifth floors, shows the presence of a secondary frequency at about 5.0 Hz that appears related to the vibration of an adjacent smaller edifice.

The damping of the building, evaluated through the Random Decrement Method, showed values ranging between 1.24% e 2.79% which are significantly lower than 5% which represent the value of the in force regulation. The evaluation of the existence of torsional effects, carried out through the simplified equation of Grimaz *et al.* (2011), set into evidence the existence of possible torsional effects as a consequence of a seismic input.

Finally, the HVSR obtained from measurements performed in the neighbour of the building showed the presence of dominant spectral peaks at about 8.0 Hz. This allow us to leave out the possibility of significant soil-to-structure interferences since the fundamental frequencies of the building and the site are quite different.

Acknowledgements. The present study was performed in the frame of an agreement between the University of Catania and the Department of Biologic Geologic and Environmental Sciences of the University.

References

Eurocode8; 2003: *Design of structures for earthquake resistance-Part 1: general rules, seismic actions and rules for buildings, EN 1998*. European Committee for Standardization, Brussels.

Faccioli E., Pessina V.: 2000; *The Catania Project: earthquake damage scenarios for high risk area in the Mediterranean*. CNR-Gruppo Nazionale per la Difesa Terremoti, Roma, p. 225.

Gallipoli M.R., Mucciarelli M., Vona M.; 2008: *Empirical estimate of fundamental frequencies and damping for Italian buildings*. Earthquake Eng. Struct. Dyn. 38, 973–988.

Gallipoli M.R., Mucciarelli M., Šket-Motnikar B., Zupanc´ic´ P., Gosar A., Prevolnik S., Herak M., Stipc¡evic´ J., Herak D., Milutinović Z., Olumćeva T.; 2009: *Empirical estimates of dynamic parameters on a large set of European buildings*. Bull. Earthq. Eng. http://dx.doi.org/10.1007/s10518-009-9133-6.

Grimaz S., Barazza F., Malisan P.; 2011: *Ambient-noise measurements for seismic risk mitigation of school buildings*. Environmental semeiotics. 4, 55-62.

Lombardo G., Coco G., Corrao M., Imposa S., Azzara R., Cara F., Rovelli A.; 2001: *Results of microtremor measurements in the urban area of Catania (Italy)*. Boll. Geofis. Teor. Appl. 42 (3–4), 317–334.

Messele H., Tadese K.; 2002: *The study of seismic behaviour buildings located on different site in Addis Ababa (Ethiopia) by using microtremors and analytical procedure. Joint study on microtremors and seismic microzonation in earthquake countries*. Workshop to Exchange Research Information, Hakone-Gora, Kanagawa, Japan.

Monaco C., Catalano S., De Guidi G., Gresta S., Langer H., Tortorici L.; 2000: *The geological map of the urban area of Catania (Eastern Sicily): morphotectonic and seismotectonic implications*. Mem. Soc. Geol. Italy 55, 425–438.

Panzera F., Lombardo G., Monaco C., Di Stefano A.; 2015: *Seismic site effects observed on sediments and basaltic lavas outcropping in a test site of Catania, Italy*. Natural Hazards, doi: 10.1007/s11069-015-1822-7

Panzera F., Rigano R., Lombardo G., Cara F., Di Giulio G., Rovelli A.; 2011: *The role of alternating outcrops of sediments and basaltic lavas on seismic urban scenario: the study case of Catania, Italy*. Bulletin of Earthquake Engineering 9 (2), 411-439

Parolai S., Facke A., Richwalski S.M., Stempniewski L.; 2005: *Assessing the vibrational frequencies of the Holweide Hospital in the city of Cologne (Germany) by means of ambient seismic noise analysis and FE modelling*. Nat. Hazards 34, 217–230.

SESAME; 2004: *Guidelines for the implementation of the H/V spectral ratio technique on ambient vibrations: Measurements, processing and interpretation*. SESAME European Research Project WP12, deliverable D23.12, at http://sesame-fp5.obs.ujfgrenoble. fr/Deliverables, 2004.