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APPLICATION OF HVSR ON REINFORCED CONCRETE BUILDINGS

Fragkiskos PENTARIS[1] and Filippos VALLIANATOS[2]

This work studies ambient noise on buildings and free field along with seismic excitation on buildings. The method which acceleration recordings are analyzed and tested is horizontal to vertical spectral ratio technique (HVSR). This method is used on free field for site amplification assessment (soil resonance frequencies) but the implementation on buildings is limited (Sungkono, Warnana, Triwulan, & Utama, 2011; Triwulan, Utama, Warnana, & Sungkono, 2010). The proposed study applies HVSR technique in buildings to reveal structures fundamental frequency. Furthermore HVSR recordings are applied on each floor of case study buildings, and the corresponding HVSR values are used in order to present the building internal differential acceleration drift between floors. This building acceleration internal drift is correlated with the maximum allowed differential acceleration between floors and such the structural vulnerability of case study buildings. Results reveal that HVSR is an easy, fast, economical method not only for site amplification but also for estimation of fundamental frequency of structures along with an assessment method for building vulnerability estimation. HVSR of ambient noise vibrations in case study structures are compared with HVSR of seismic activity recordings for the same buildings, presenting the same analogy in HVSR increase as floor is getting higher. This analogy contributes that a simple HVSR recording of with or without earthquake excitation could reveal internal drift acceleration under the seismic vibration response. A novel method of correlation of HVSR change between floors is proposed. The work studies this novel approach of HVSR technique through two 3 floor concrete public buildings of different age, under different time periods and under different type of excitations (ambient, seismic, human made).

Case study includes two different university buildings, which are attached to each other on one side. They have different construction material, and different year of construction. In more detail, the two buildings host the Chania branch of the Technological Institute of Crete (Pentaris, Stonham, & Makris, 2013). Building (A) is built on the west side in 1995, with concrete, glass and steel, while building (B) is built on the east side in 2007 with concrete. Table 1, presents characteristics for both buildings, and figure 3 illustrates schematic diagram of the two buildings, showing the sensor's location.

Table 1. Characteristics of the Technological Institute buildings at Chania

Building Code	Age (years)	Size(m)	Shape (Direction)	Floor height	Number of rooms	Number of floors
A	19	30,62*18,03	Rectangle (NS)	3.65	7	4
		11.29*43.30	Rectangle (EW)	3.65	5	4
B	7	51.55*21.85	Rectangle (NS)	3.67	15	4

[1] Mr, Brunel University, London, fragkiskos.pentaris@brunel.ac.uk
[2] Dr, Technological Educational Institute of Crete, Chania, fvallian@chania.teicrete.gr

Figure 1 reveals the HVSR analysis of the seismic event of figure 10, as it was recorded by the SMA accelerometers on TEI buildings at Chania (old and new building). The acceleration time series have been separated in three time duration zones (red, green and blue) with 25 seconds time duration, each time window. Red window contains the “primary wave” of the earthquake, green the “secondary wave” and blue the “after the secondary wave”. Figure presents that the amplitude of HVSR plot is higher as the energy is getting higher. Such the HVSR amplitude plot of P-wave is much lower than the S-wave plot. Also the HVSR amplitude rises as the floor rises.

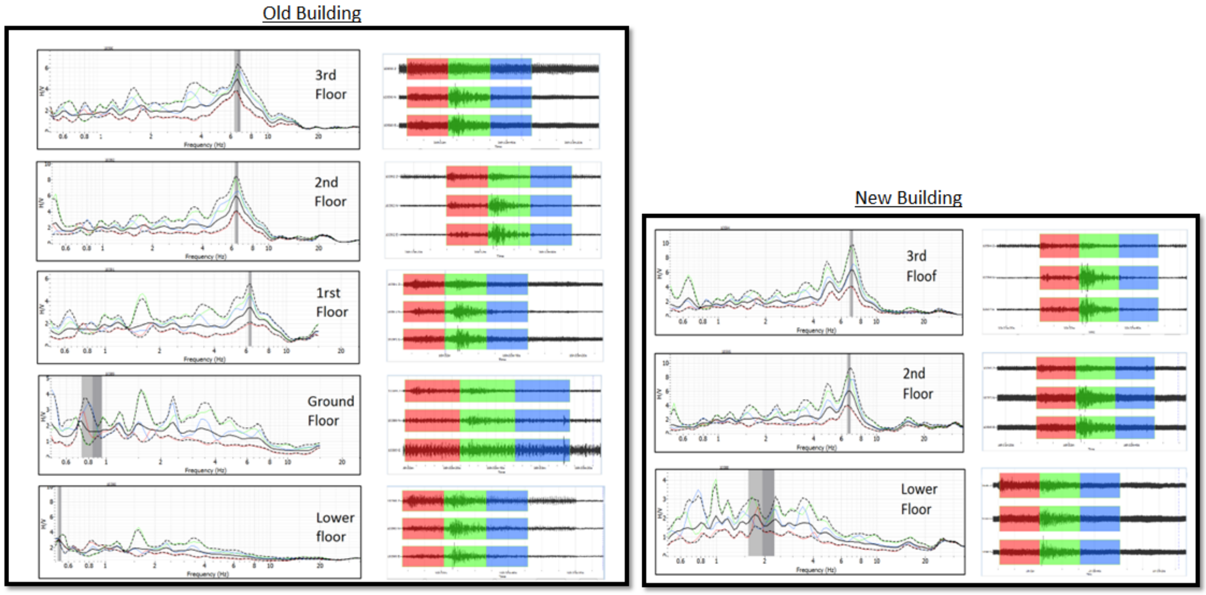

Figure 1.HVSR recordings on 2013/04/28 16:33 UMT (2013/04/28 19:33 local time) on the old (left) and new (right) building of TEI in Chania for the above seismic event. With red colour is 25 sec window of P-wave, with green the 25 sec window of S-wave and with blue the 25sec window of after S-wave window

An index is proposed which presents the change of HVSR of the fundamental frequency of the structure from one floor to another. As the HVSR increase the influence of site amplification in the specific structure increases. And if the HVSR increase on higher floors it indicates that there is higher vulnerability of the structure in higher floors. The fundamental frequency of HVSR recordings at each floor is being measured and there is comparison of the increase of the value of HVSR, and it is correlated this rise with the increase of probably vulnerability of the structure.

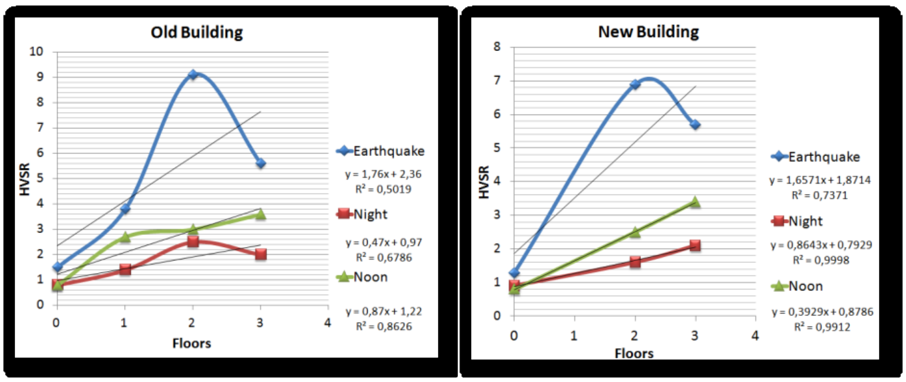

Figure 2. HVSR recordings from the on 2013/03/09 07:43 UMT time seismic event (Blue line), the 2013/03/12 midnight recording (red line) and the 2013/03/12 noon recording of the old (left figure) and new (right figure) building of TEI in Chania

Horizontal to vertical spectral ratio (HVSR) and Receiver Function (RF) methods, have been applied in microtremors and earthquake acceleration recordings, in order to study the resonances frequencies and their spectral amplitude, that exist in two concrete buildings, in a high seismogenic region. These frequencies are in the range 5,5-6,5 Hz. The site amplification on the area that case study buildings are located, is much lower (arround 0.7 Hz). The HVSR rise as floor gets higher. In this study the increase of HVSR is strongly related with the age of the buildings and the visible cracks in the beams. HVSR also indicates higher differential acceleration from floor to floor and such higher structural vulnerability. This work presents an approach of HVSR by implementation of the method for structural health monitoring. More specifically it applies HVSR in each floor of buildings, finds out the different HVSR values and suggests a new index which compares and analyses the HVSR of the fundamental frequency in each floor of a building and how this value changes. Also it searches the possibility of correlation of this value with the vulnerability of a building and presents that as HVSR rises as floor gets higher the vulnerability of the building could rise for these floors. Analysis of building vulnerability provided by HVSR and/or RF method, is a very cost effective and fast method which use simple acceleration recordings and could provide information for structural vulnerability.

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