United Nations Educational, Scientific and Cultural Organization

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Is the Evaluation of Topographic Effects an Easy Task?

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The effects of topography have been widely studied through several analytical and numerical methods (e.g., Paolucci, 2002), instrumental evidences of topographic effects are however relatively few. Experimental techniques for investigating the topographic effects are quite expensive since they require the setting down and operation of the instruments for an undefined period of time to acquire earthquakes. For this reason, records of explosions and noise measurements can be very useful to estimate these site effects. Although such techniques have been rarely used to investigate on topographic effects, rather satisfactory results have been obtained (e.g. Pagliaroli et al., 2007; Panzera et al., 2011).

An important aspect, in topographic amplification estimates, concerns the difficulty to distinguish between a purely topographic effect and the influence of different local lithology amplification. In particular, the amplification of seismic motion at the top of a hill might be caused by other phenomena, such as the presence of fractured rock, near surface weathering, low-velocity layers, or fault zones near the site measurements.

The aim of present study is to estimate the seismic site response due to topographic effects of two study areas the Ortigia peninsula (Siracusa, Italy) and the university campus of Catania (Italy). The Ortigia area represents, because of its geological and morphological setting, an useful test site to perform passive experimental techniques aiming to identify the site response directivity and the fundamental resonant frequency connected to the topographic effects. It is formed by a carbonate sequence whose dynamic properties were investigated through non-invasive techniques (MASW and ReMi). The university campus of Catania, on the contrary, has a gentle topography with a flat surface at the top and it is characterized by a complex sedimentary sequence laying between a clayey basement and an upper volcanic formation. The lithologic heterogeneities, existing in the Catania area, seem to have a stronger influence with respect to the simple topographic effect.

The evaluation of local seismic response of the two study areas was undertaken by integrating different experimental approaches. The data used in this study consist of both noise and earthquake recordings that were processed through horizontal to vertical spectra ratio (HVSR), horizontal to vertical noise spectra ratio (HVNR) and standard spectral ratio techniques considering horizontal (HSSR) and vertical (VSSR) components. Experimental spectral ratios (HSSR, HVSR, HVNR) were also calculated after rotating the NS and EW components of motion by steps of 10 degrees starting from 0° (north) to 180° (south). This approach, firstly applied to earthquake recordings in studying the directional effects due to topographic irregularities at Tarzana, California (Spudich et al., 1996), has been also widely adopted, for similar purposes, using ambient noise signals (Del Gaudio et al., 2008; Burjànek et al., 2010; Panzera et al., 2011). A direct estimate of the polarization angle, for both earthquakes and noise data, was achieved by using the covariance matrix method (Jurkevics, 1988). This technique is very efficient in overcoming the bias linked to the denominator behavior that could occur in the H/V's technique.

The homogeneity of the carbonate sequence outcropping in the Ortigia peninsula and its simple convex morphology made it ideal for investigate topographic site effects. The HVNR show dominant frequency peaks in the range that is in good agreement with the theoretical resonance frequency of the hill, computed using experimental shear wave velocities. Moreover, both the directional resonance and the polarization analysis confirm the presence of a directional effect having an azimuth transverse to the major axis of the ridge. The investigation on the characteristics of the site response at the university campus of Catania, has instead set into evidence that the complexity of the near-surface geology, as well as the morphology strongly influence the local amplification of the ground motion and the directivity effects.

Finally, as a practical implication of present study it can be set into evidence that the topographic effects cannot be easily evaluated especially when subsurface morphology and lithologic features are predominant.