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An Ambient Noise HVSR Survey in Valletta World Heritage Site and the Historical City of Mdina, Malta

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In this paper we report preliminary results of the measurements of ambient noise on a dense network of measurement sites in and around the cities of Valletta and Mdina; two important historical heritage sites in Malta. The city of Valletta is the present capital of Malta and it is inextricably linked to the history of the military and charitable Order of St John of Jerusalem. Valletta with its 320 monuments is a UNESCO World Heritage site. All the monuments are contained within quite a small area, making it one of the most concentrated historic areas in the world. The city of Mdina is the old capital of Malta. Mdina is situated in the centre of the island and is a medieval town still confined within its walls. It is a small town with rich history, monuments and cultural heritage. The seismic microzonation studies, which have not been previously performed on Malta, are an important component of risk evaluation and the preservation of prominent cultural heritage sites.

The seismic history of the Maltese islands is adequately documented since around 1500 (Galea, 2007). In the past, Malta has been struck by several earthquakes. The largest intensity (VII – VIII) was experienced on 11 January 1693, from the magnitude 7.4 event most likely originating on a NNW-SSE trending fault segment of the Hyblean-Malta escarpment offshore Syracuse. Extensive damage was reported in almost all built up areas of the time, including partial collapse of the Mdina cathedral and structural damage to many buildings (Azzopardi, 1993). Significant damage was also reported in the area of Valletta and several induced landslides and rock falls are documented.

We used the Nakamura (1989) technique to derive the spectral ratio of horizontal and vertical component (HVSR) of microtremors. The great advantage of the method is that it offers valuable data on soil properties at very low-cost. We used the SESAME (Site EffectS assessment using AMbient Excitations; http://sesame-fp5.obs.ujf-grenoble.fr) guidelines to ensure validity of the results. Ambient noise measurements in Mdina and Valletta were conducted in three campaigns in May, September, and November 2011. In total, we acquired data at about 60 locations using a portable 3-component seismometer Tromino® manufactured by Micromed. Each measurement lasted for 20 minutes and the three orthogonal components of the noise were recorded at 128sps. The records were processed using the Grilla® software. Several points were located in the urban areas of Valletta and Mdina, where the urban noise (transient) is quite high during the day time. For this reason we performed several measurements during the night to considerably improve the quality of the data.

One of the important aspects of ambient noise measurements is the modelling of the wave field to establish a link between the observations and the subsoil structure. For this purpose we used the ModelHVSR Matlab routines (Herak, 2008). The program allowed us to verify existing geotechnical models by comparing theoretical HVSR to the observed one and we also obtained the most likely preliminary geotechnical models of the soil. In order to perform the modelling we used the velocity values for the different Maltese geological formations

proposed by Panzera et al., (2011) and obtained by applying ReMi®, MASW and Refraction methods.

We processed the data considering the SESAME criteria highlighting the main features of the sites in terms of predominant frequency and amplitude of the spectral ratio. Several sites show flat HVSR curves, whereas clear peaks were obtained at other locations. This is consistent with the underlying geology of the investigated sites. In particular, on top of the hill where the city of Mdina is located and where the hard Upper Coralline Limestone (UCL) is outcropping, measurements showed peak amplitudes greater than 2 in most cases. This amplification is likely to be due to the Blue Clay layer underlying the UCL. The Blue Clay layer results in a velocity inversion, which is evident in the HVSR curves obtained at several locations, where the curve drops below 1 over a wide frequency range. The amplification due to the buried clay layer has important implications in microzonation analysis where the outcropping geology would indicate a hard rock site and hence a zone of no amplification.