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Research Article

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Preliminary Remarks on the Soil-Related Earthquake Hazard in Buyukada/ Prinkipo (Istanbul)

Ferhat Ozcep[1], Savas Karabulut[1], Okan Tezel[1], Faruk Caglak[2], Oguz Ozel[1]

[1]Istanbul University, Geophysics, Istanbul, Turkey
[2]Istanbul University, Underwater Technology, Istanbul, Turkey

Abstract Büyükada (or Prinkipo in Greek) is important district in Turkey as a unique part of all the world's culture and civilization with natural, historical and human values. As the largest one of the nine islands comprising the Princes' Islands in the Marmara Sea, close to Istanbul, Buyukada ("Large Isle") consist of with an area of 5.46 km^2. The main factor controlling the earthquake hazard for Istanbul is a complex fault system, i.e. the North Anatolian Fault zone, which in the Marmara Sea region. Recent geophysical studies have carried out that this hazard is mainly associated within two active seismogenic areas: the Central Marmara Basin and the Adalar Fault zone, located about 15-30 km south-west and south of Istanbul. Eartquake ground motion affects the structures via the state of the soils. There are several historical buildings on Büyükada, such as the Ayia Yorgi Church and Monastery dating back to the sixth century, the Ayios Dimitrios Church, and the Hamidiye Mosque built by Abdul Hamid II and Greek Orphanage, a huge wooden building etc. The soils and buildings with characteristics of earthquakes could be caused an earthquake damage / loss. One of the most important factors in reducing the earthquake risk in urban areas due to the earthquake ground motion is to estimate ground motion level with interaction of soils. When we look at the geological structure of Buyukada, Paleozoic unites and alluvial deposits are located. Site response of alluvial deposits in Buyukada is also important for the behavior during an earthquake. Geophysical study in the study area in order to estimate the behavior of soils is carried out to obtain the dominant period (microtremor measurements) and shear wave velocity (MASW - MAM measurements) data. Soil geophysical results is input to earthquake motion for bedrock sites, and is important to the interaction with the ground movement and the soils to estimate Büyüka's earthquake ground motion. In the earthquake-soil interaction, spectral acceleration is an important criterion. In this study, spectral acceleration are also estiamted for ground motion level in Princes' Islands by using several approaches.

Keywords Soil Dynamics, Buyukada/Prinkipo, Geophysical Properties, Site Effects

1. Introduction

One of the the most important objectives of urban / regional planning and urban transform planning is to provide a safe and healthy life. Our efforts to reduce the risk remains insufficient (Wenzel and Bendimerad, 2004) because an interaction between irregular urbanization and natural disasters increased risk curve (Figure 1). One of the princes' Isles is known in Turkish as Buyukada, in Greek as Prinkipo that is the largest and the most populous and have always a maritime suburb of Istanbul, the great metropolis on the Bosphorus, Greek Constantinople, ancient Byzantium [1]. A great earthquake were ocurred in Istanbul and its environs on 10 July 1894. Due to the earthquake, there also was a lot of damage at Buyukada/Prinkipo. North Anatolian Fault zone is one of the most important strike slip faults in Turkey. The Princes Island segment is one of three active segments of the Northern Anatolian Fault. Earthquake-soil interaction could be one of the main reasons for damage due to the soil amplification and/or liquefection events [2-3]. The aim of the study is to present the geophysical properties of the soils with interaction of earthquake ground motion in Buyukada/ Prinkipo (Istanbul).

Earthquake Hazard and Local Geology

Deterministic and probabilistic analyses could be used to evaluate the seismic hazard in the region [4-5]. The potential earthquake source area was considered to be the North Anatolian Fault [6-7] beneath the Marmara Sea. Figure 2 shows historical (32 AD –1900) seismicities of major earthquakes in the region are shown with major and minor fault systems.

Buyukada was formed in the last glacial period. The geology of the region was firstly investigated by Swan (1868) [8]. The other interesting study were carried out by Ketin (1953) [9]. Buyukada (Istanbul) geologically has many Paleozoic aged units. Local formations are called as Aydos formation, Kurtköy formation, Gözdag formation, Dolayoba formation, Kartal and Tuzla formation. There are also some volcanic intrusions and alluvial formations. The alluvial sediments in Buyukada is also important in the seismic behavior during earthquakes. Geologic unites with geophysical measurement locations are shown in Figure 3.

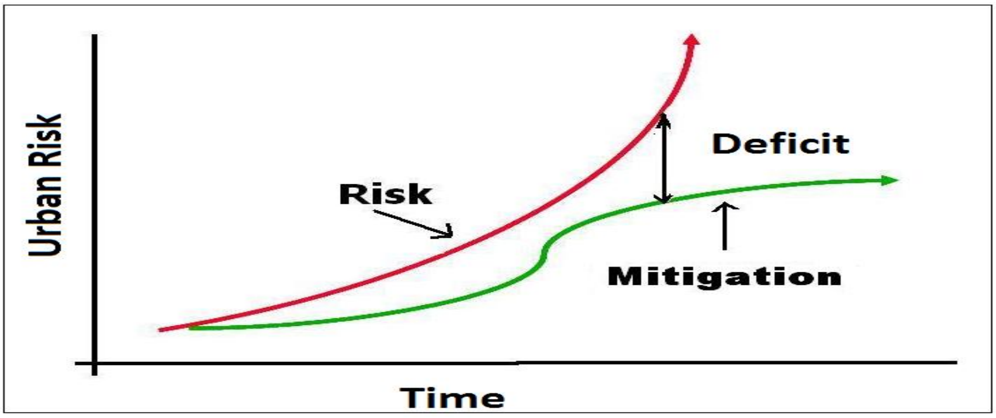

Figure 1: Urban Risk versus Time [10]

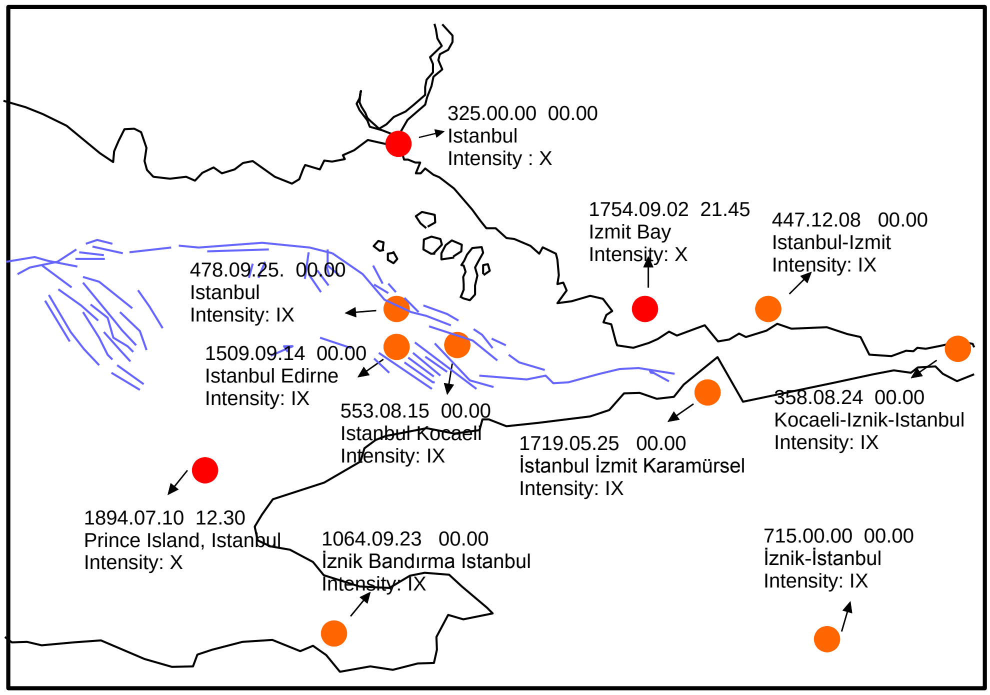

Figure 2: Historical (32 AD –1900) seismicities of major earthquakes in the region are shown with major and minor fault systems (data from KOERI)

The faults / fault segments in the North Anatolian Fault zone (NAFZ) near Buyukada is seismic source for expected earthquake for this region. This fault zone has been not active since 1766 with fault reptures [11] of 30 km, 109 km, 120 km and 174 km (Fig. 4).

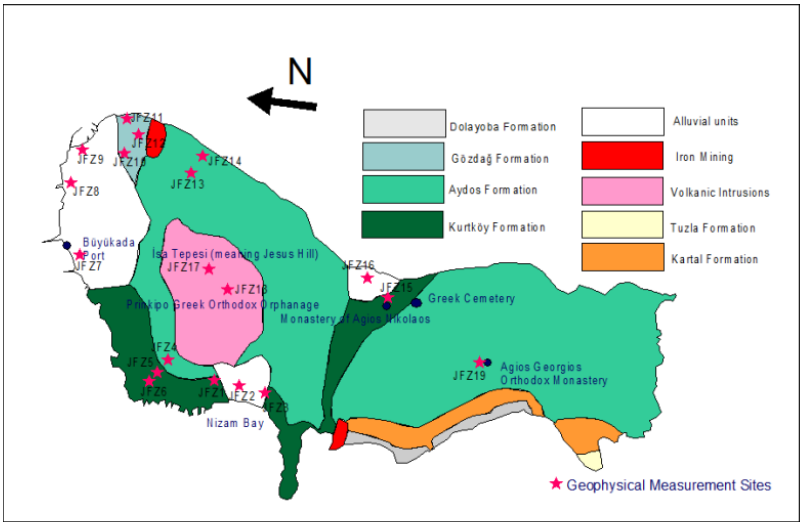

Figure 3: Geological Unites and Geophysical measurement Sites.

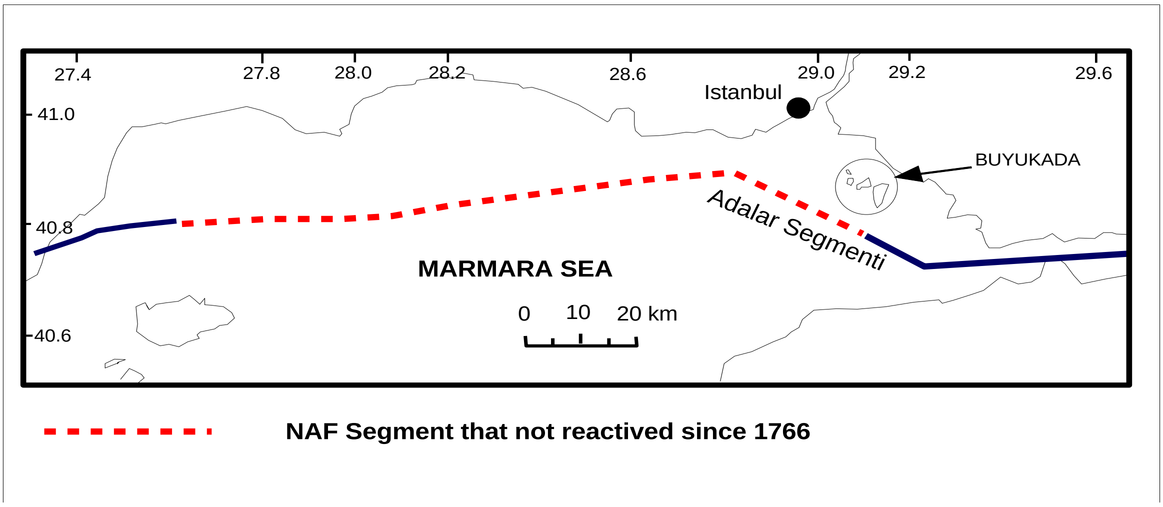

Figure 4: NAFZ main segment that not re-activated since 1766 [7]

Ground motion levels with a probabilistic seismic hazard analysis (for 50 years and exceedance rates (20% and 50%) and deterministic (Wells and Coppersmith, 1994) seismic hazard assessment for the region are estimated as M: 7.6 and as M: 6.8 by using Ozcep (2010) software.

Geophysical Properties of Buyukada Soils

In the study area, geophysical sites are considered according to the geological fromations (Fig. 3). Working in the field of two different geophysical studies in a total of 19 points (MASW-MAM and Microtremor) were conducted.

A MASW and MAM system consisting of 12 or more channels with vertical geophones of 4.5 Hz capacity were used to measure V_S. In this system, active or passive seismic waves are created as an impulsive source or man-made and natural noise The captured Rayleigh wave is further analysed using SeisImager/SW™ (2005) software to obtain V_S profiles. The SeisImager/SW™ procedure for generating V_S data in either 1-D or 2-D format is in three steps: (1) preparation of a multichannel record; (2) dispersion-curve analysis; and (3) inversion. The optimum field parameters (e.g., distance of source to first and last receiver, receiver spacing, spread length of survey lines) are selected to ensure that information is obtained for the required minimum 30 m depth. A dispersion curve is then generated from the seismic wave records. Then, using an iterative inversion process that requires the dispersion curve as input, a V_S profile is calculated. This is updated after each iteration, with the soil property parameters such as Poisson's ratio, density and thickness remaining unchanged. An initial earth model is specified to begin the iterative inversion process.

Site effects due to local soil conditions are generally expressed as the spectral ratio (S1) between the horizontal to vertical component of microtremor recordings, described by Nakamura (1989) as [12]:

$$S1 = H/V \quad (1)$$

The term 'microtremor' is used to cover all ambient noise, i.e. both man-made noise, generally high frequency, generated by local surface sources such as industry and traffic, and natural low-frequency noise generated by tides, winds, teleseisms, etc [13].

Results are summarized in Table 1. Vs30 values of soils are ranges from 227 m/s (JFZ 8 Site, in front of Buyukada Municipality) to 975 m/s (JFZ 19 Site, Agios Georgios Orthodox Church). For each site, geophysical measurements (MASW/MAM and microtremor) are given in Figure 5a to t.

Table 1: Geophysical Properties of Buyukada's Soils

Sites	Vs30 (m/s)	Fundamental Periods (s)	Soil Class (Eurcode 8)	Formations
JFZ 1	492	0,35	B	KurtKöy
JFZ 2	475	0,15	B	Alluvion
JFZ 3	311	0,35	C	Alluvion
JFZ 4	472	0,65	B	Aydos
JFZ 5	493	0,4	B	KurtKöy
JFZ 6	496	0,35	B	KurtKöy
JFZ 7	356	0,2	C	Alluvion
JFZ 8	227	0,3	C	Alluvion
JFZ 9	343	0,3	C	Alluvion
JFZ 10	362	0,3	B	Gözdağı
JFZ 11	485	0,1	B	Gözdağı
JFZ 12	249	0,3	C	Gözdağı
JFZ 13	384	0,1	B	Aydos
JFZ 14	347	??	C	Aydos
JFZ 15	578	0,15	B	KurtKöy
JFZ 16	312	0,35	C	Allluvion
JFZ 17	430	??	B	Volcanic
JFZ 18	684	??	B	Volcanic
JFZ 19	975	??	A	Aydos

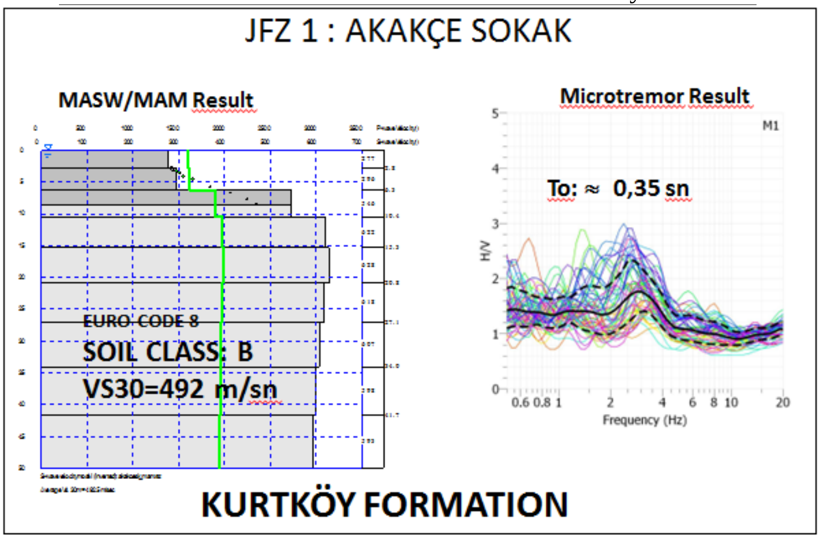

Figure 5a: Geophysical results for Akakçe Sokak

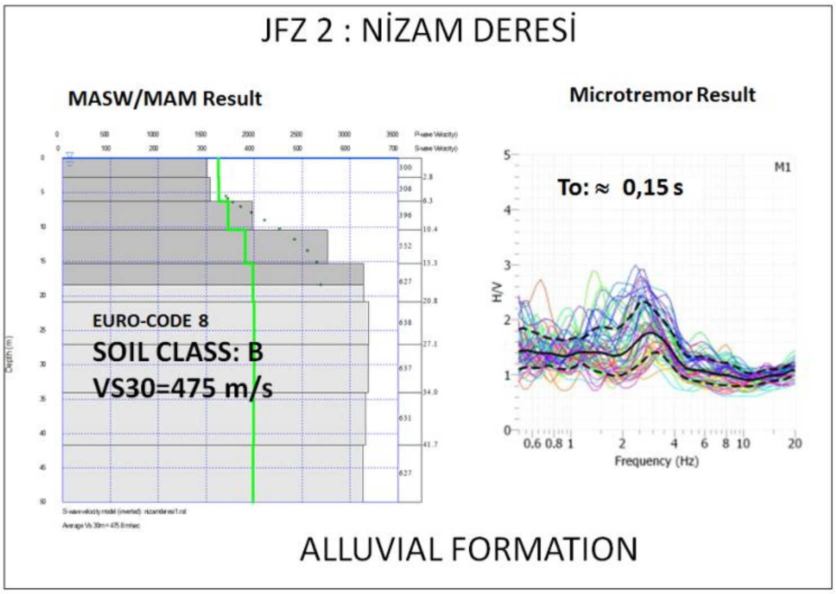

Figure 5b: Geophysical results for Nizam Deresi

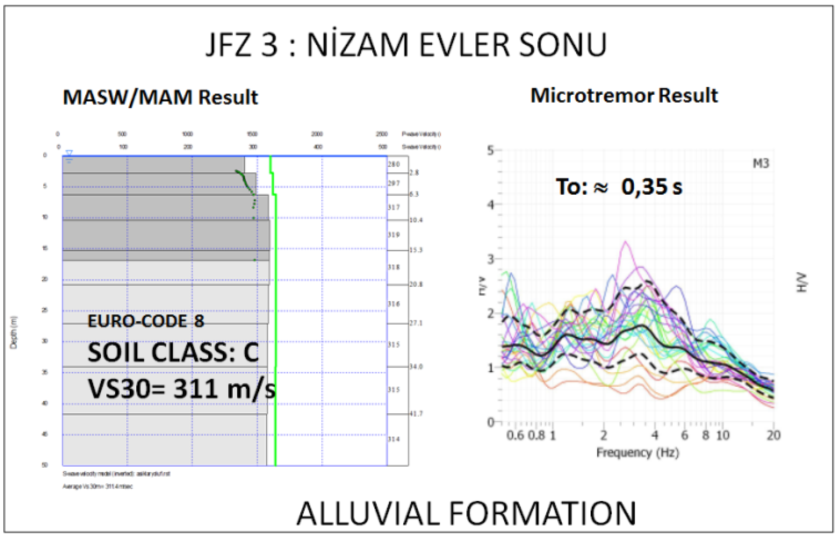

Figure 5c: Geophysical results for Nizam Evler Sonu

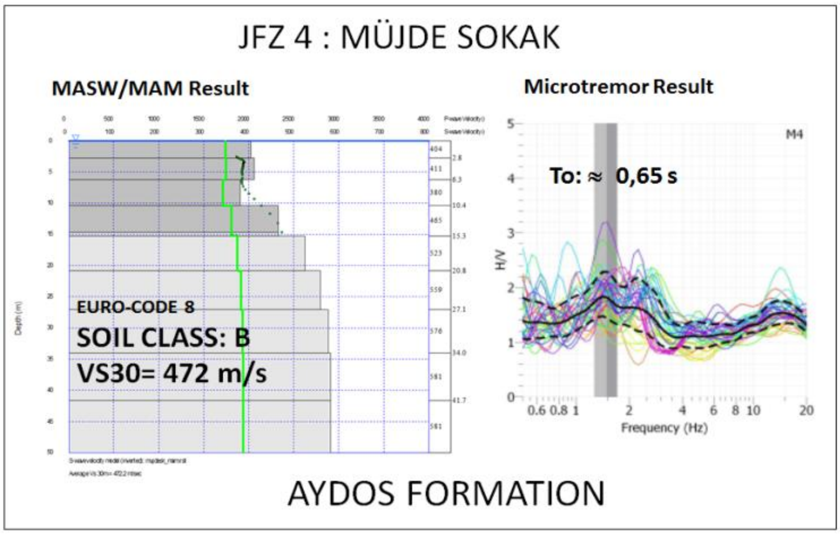

Figure 5d: Geophysical results for Müjde Sokak

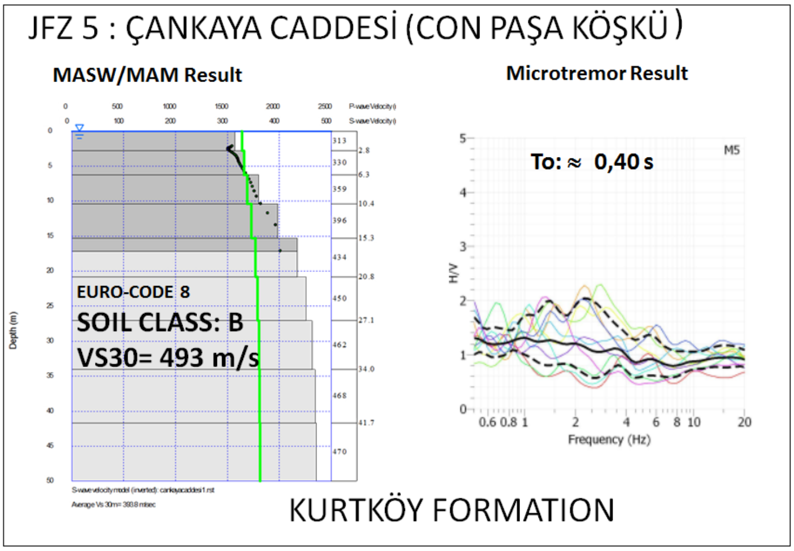

Figure 5e: Geophysical results for Cankaya Caddesi

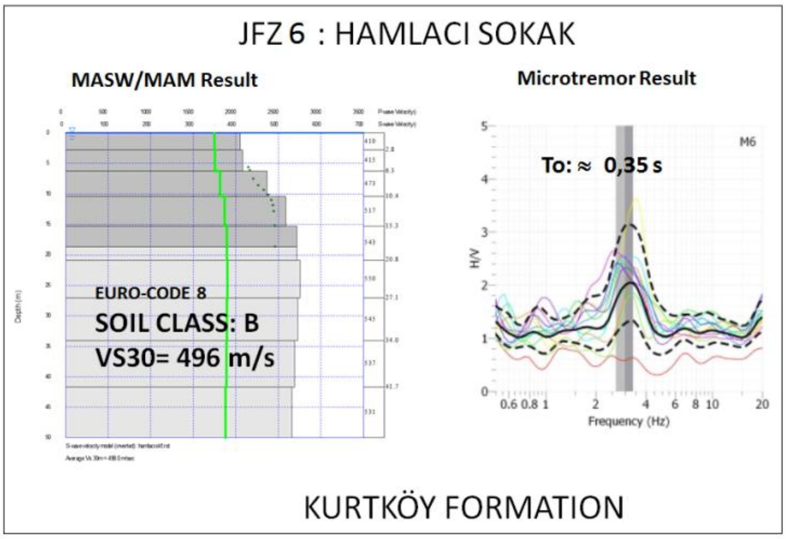

Figure 5f: Geophysical results for Hamlacı Sokak

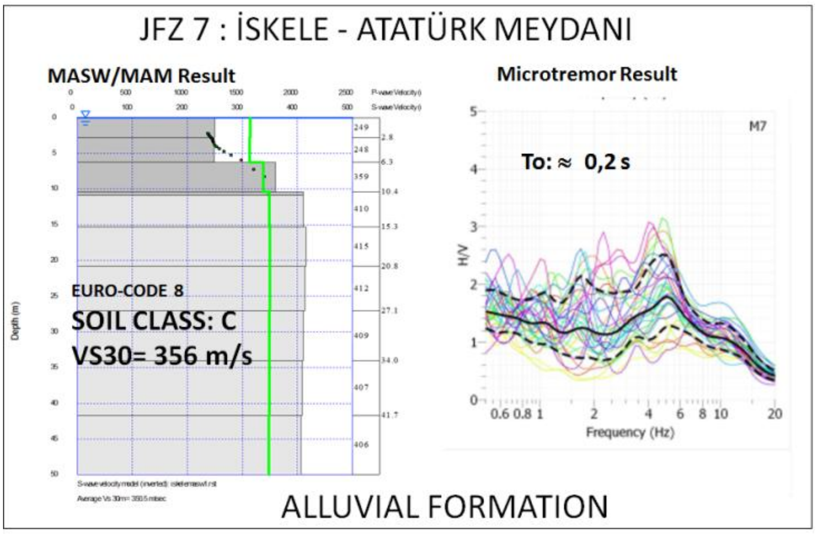

Figure. 5g: Geophysical results for Atatürk Meydanı

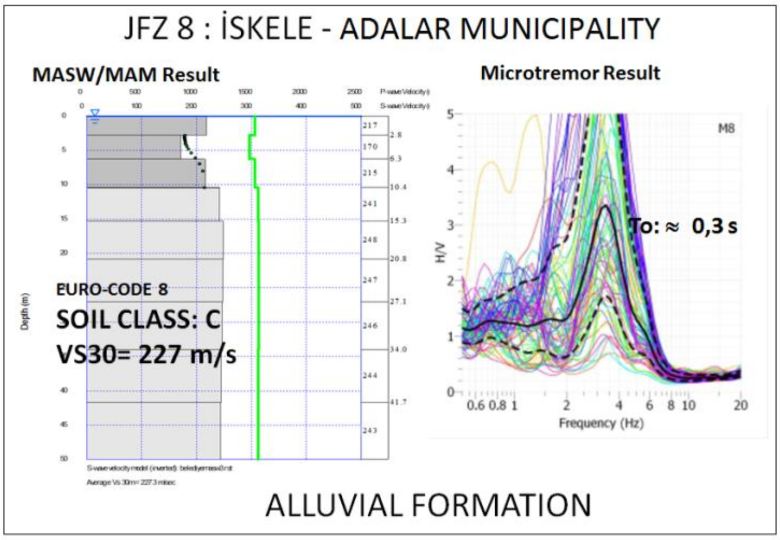

Figure 5h: Geophysical results for Adalar Municipality

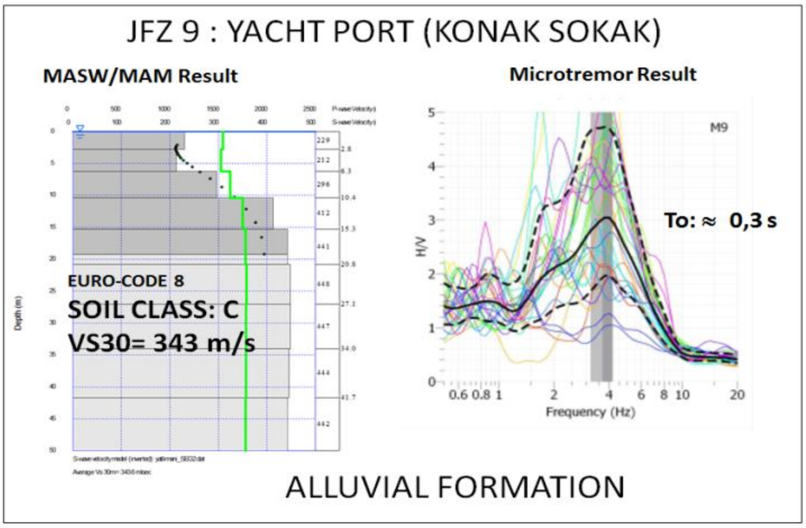

Figure 5i: Geophysical results for Yacht Port

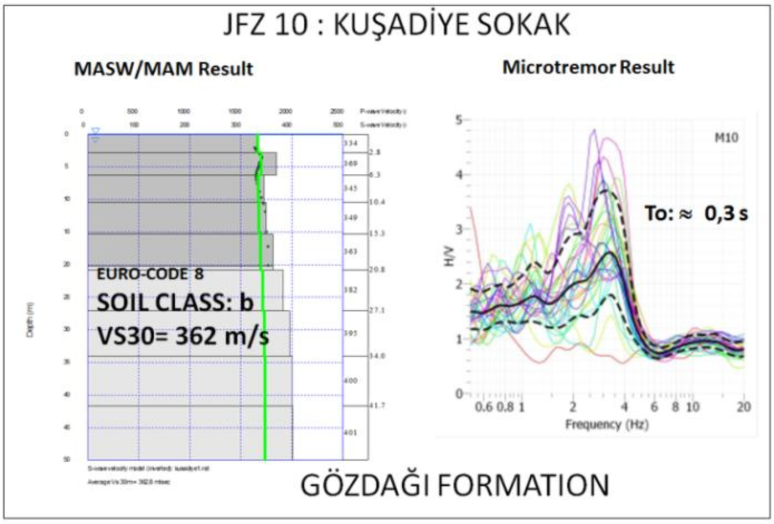

Figure 5j: Geophysical results for Kuşadiye Sokak

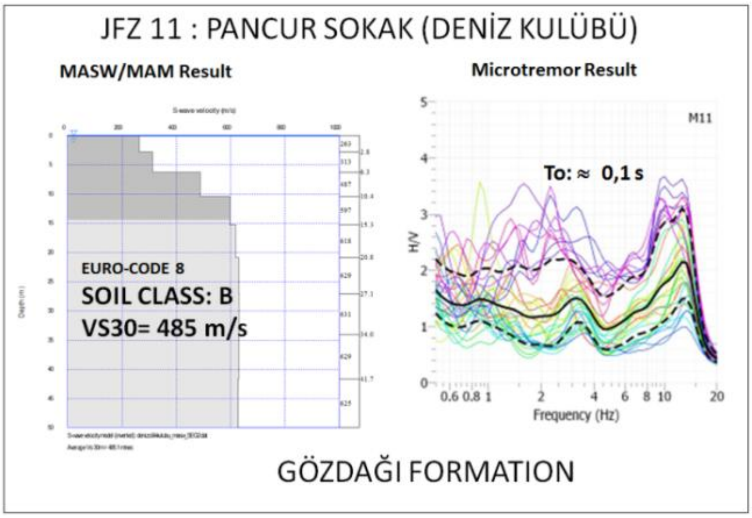

Figure 5k: Geophysical results for Pancur Sokak

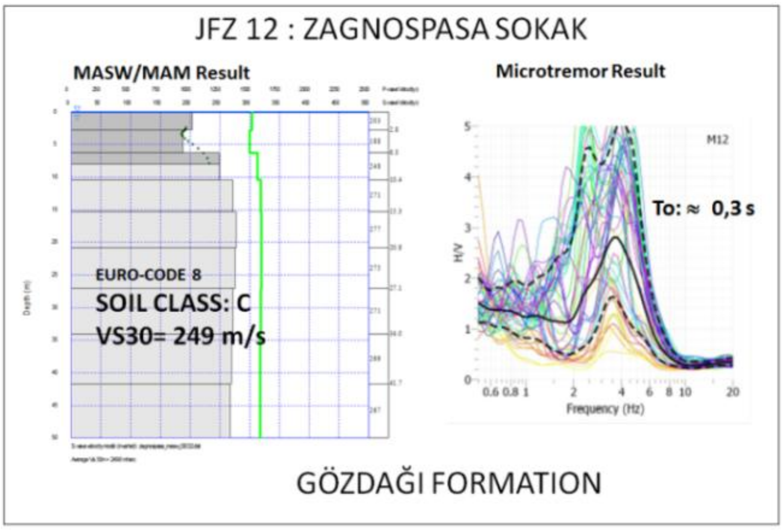

Figure 5l: Geophysical results for Zagnospasa Sokak

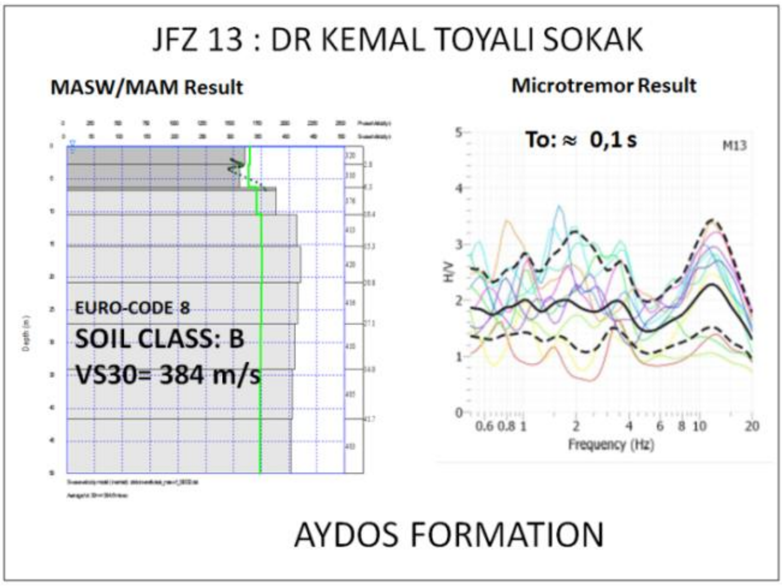

Figure 5m: Geophysical results for Dr. Kemal Tonyalı Sokak

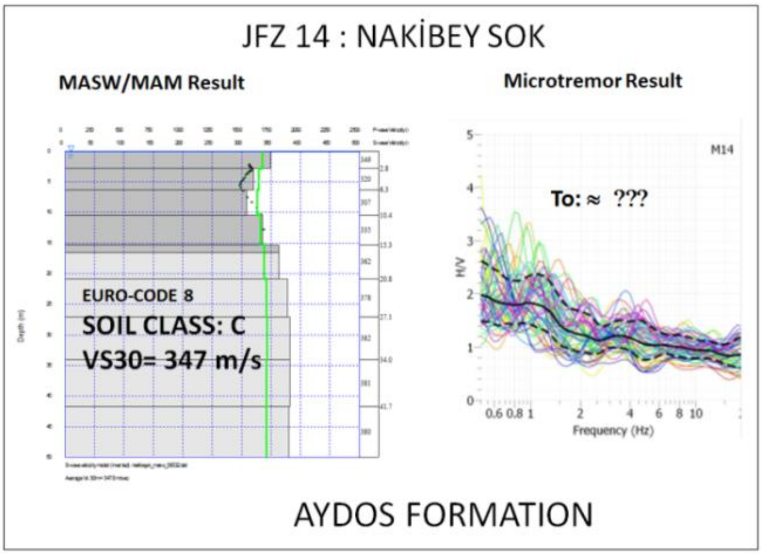

Figure 5n: Geophysical results for Nakibey Sokak

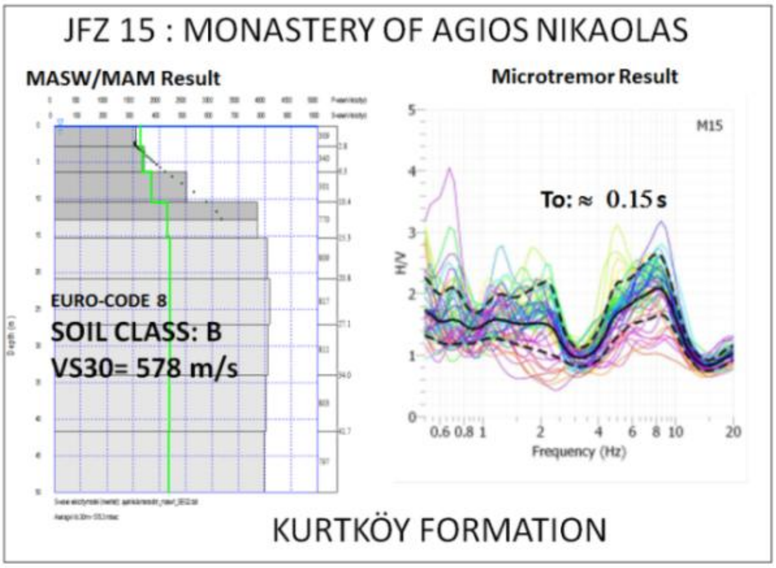

Figure 5o: Geophysical results for Agios Nicolas

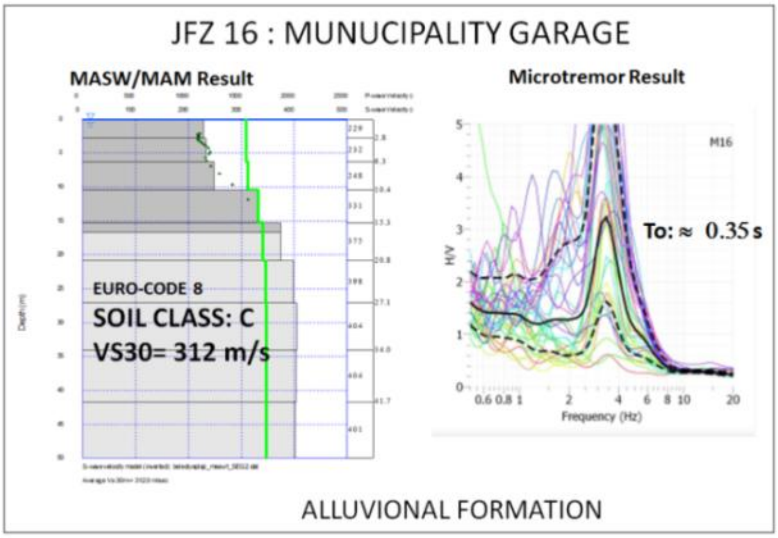

Figure 5p: Geophysical results for Municipality Garage

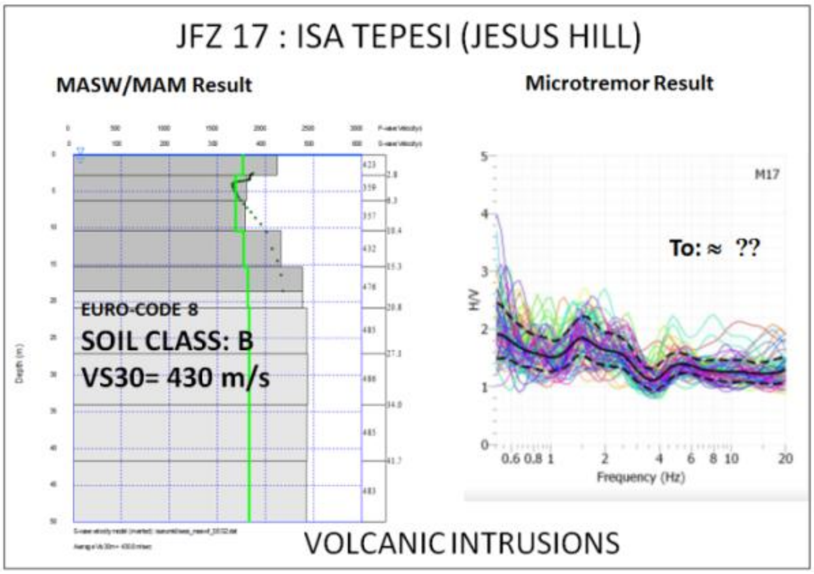

Figure 5r: Geophysical results for Jesus Hill

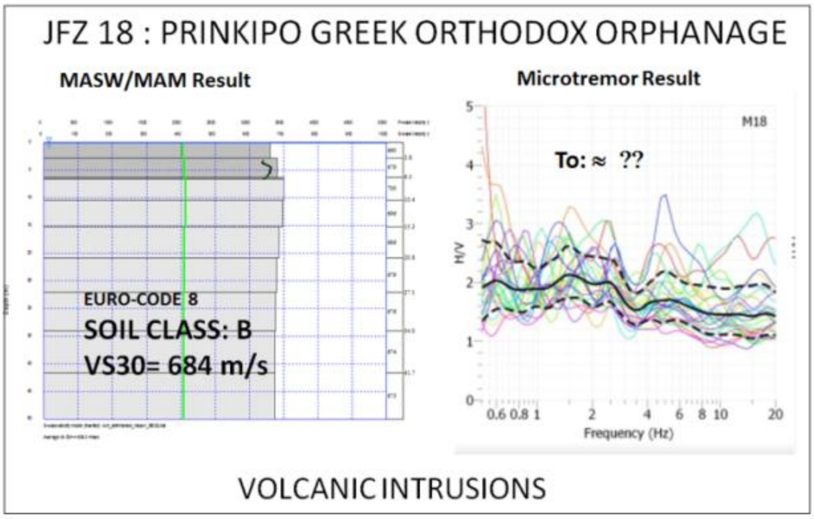

Figure 5s: Geophysical results for Orthodox Orphange

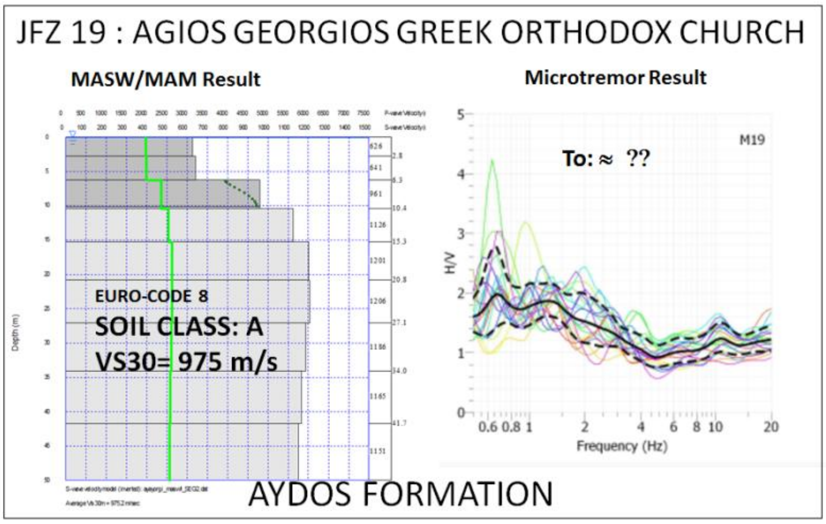

Figure 5t: Geophysical results for Agios Georgios

Ground motion leve with interaction of soil conditions

Number of earthquake event in the instrumental period are shown in Table 2 for 95 years of interval. Magnitude-frequency relationship for study area are shown in Figure 6. From this data, ground motion levels are estimated by using the probabilistic and deterministic seismic hazard analysis. For 50 years and two exceedance rates (20% and 50%), design earthquake magnitudes are taken M: 7.6 and as M: 6.8 for the region.

Table 2: Number of Earthquake event

Magnitudes	**4.5 ≤ M <5.0**	**5.0 ≤ M < 5.5**	**5.5 ≤M <6.0**	**6.0 ≤ M <6.5**	**7.0≤ M <7.5**
Number of Events	23	9	6	1	3

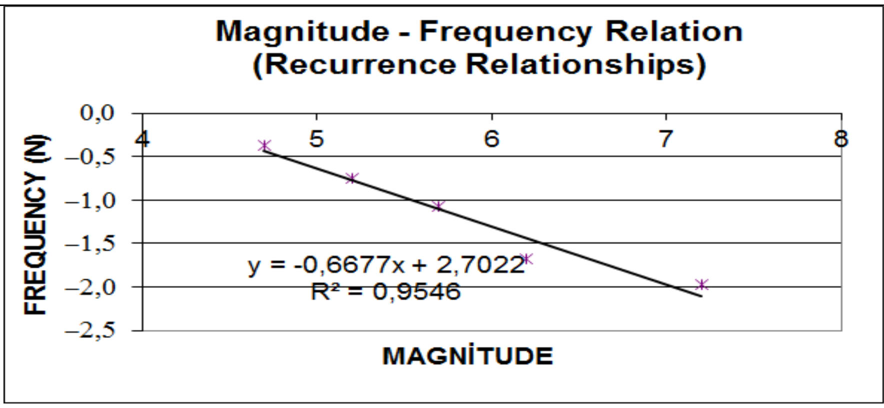

Figure 6: Magnitude-frequency relationship for study area.

For the study area, ground motion levels (acceleration) are estimated [14-15] by using soil conditions (Vs values) and are estimated the spectral accelerations by [14]:

lna = b1 + b2 (M-6)-b3 (M-6) 2-b5 ln (R) - bv ln (Vs / Va)

Here; a, acceleration for corresponding period as g, Vs, the first 30 m to the soil average shear wave velocity, R = (rjb^2 + h^2); Rjb: the closest horizontal distance (km) to fault. M: moment magnitude), b1, b2 , b3, b5 are the constant coefficients.

In the second approach [15], spectral acceleration values depending on soil conditions were estimated in the following equation:

$\log(PSA) = b_1 + b_2 M + b_3M^2 + (b_4 + B_5M)\log\ (R_{jb}^2\ b_6^2)^{0.5} + b_7S_s + b_8S_A + B_9F_N + B_{10}F_R + \sigma$

Here; PSA is acceleratiıon for the relevant period as cm/sn^2; F_N and F_R are fault coefficients; for normal and reverse faults : 1, Strike-slip faults : 0 . S_S and S_A are soil coefficients, Vs is less than 350 m/s, than they are 1, otherwise are 0. R_{JB} is the closest horizontal distance (km) to fault (km). M is moment magnitude. b_1, b_2, b_3, b_4, b_5, b_6, b_7, b_8, b_9, b_{10} are coefficients. σ is the standard deviation. Figure 6a to d shows the results of Akkar and Bommer (2009) approach [15]. The results of second approach are presented in Figure 7a to d. We are assumed in each models that scenario magnitudes of possible earthquake are 6.8 and 7.6. Soil input for these models are represented by VS30 as min:227 m/s and max: 970 m/s.

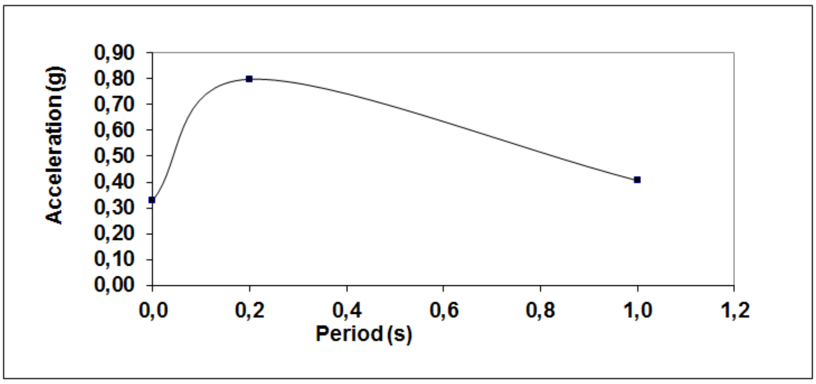

Figure 7a: Spectral Accceleration for M:6.8 and Vs30: 227m/s

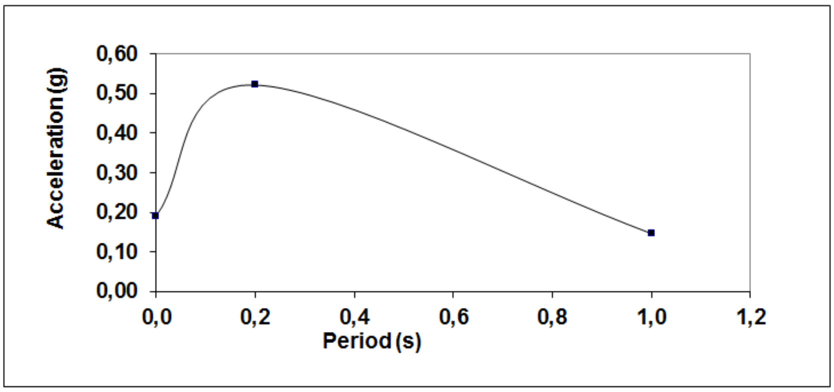

Figure 7b: Spectral Accceleration for M:6.8 and Vs30: 970m/s

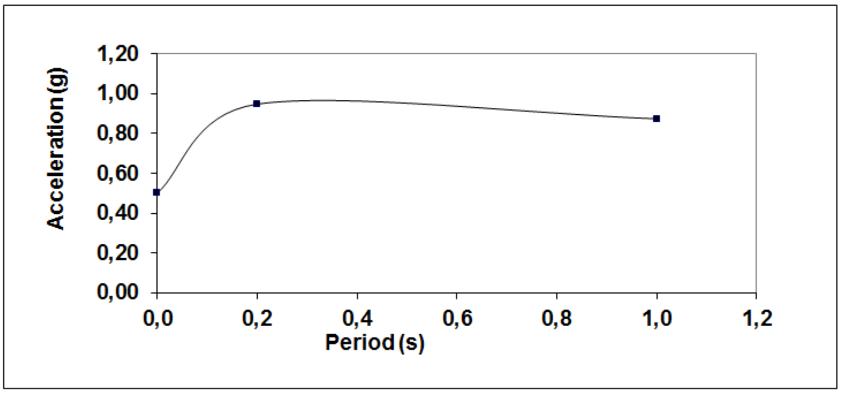

Figure 7c: Spectral Accceleration for M:7.6 and Vs30: 227m/s

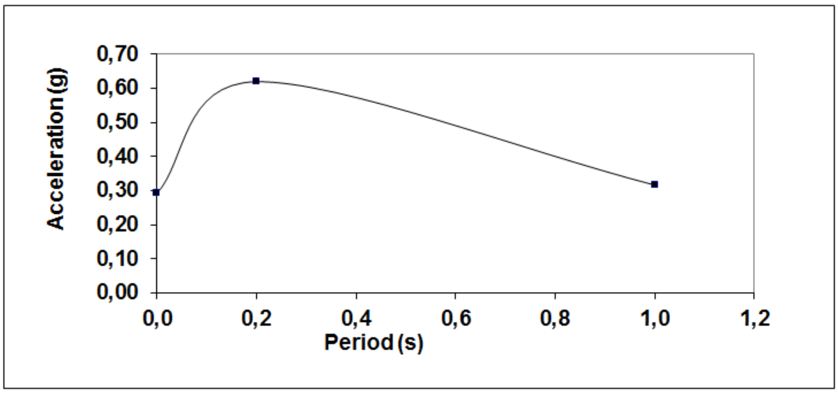

Figure 7d: Spectral Accceleration for M:7.6 and Vs30: 970m/s

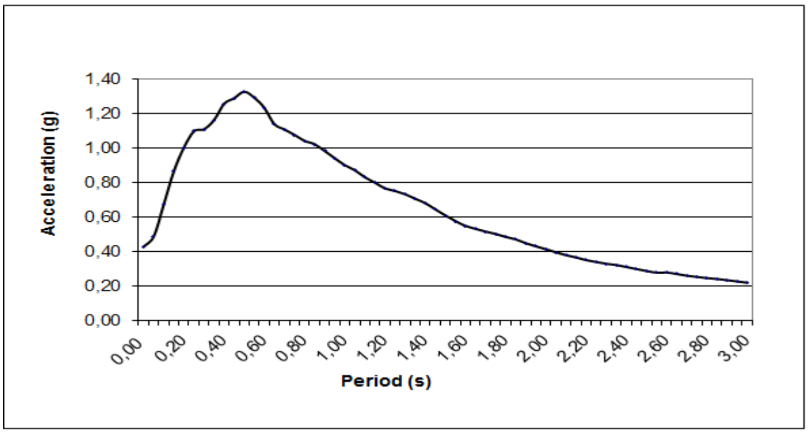

Figure 8a:. Spectral Accceleration for M:6.8 and Vs30 < 350 m/s

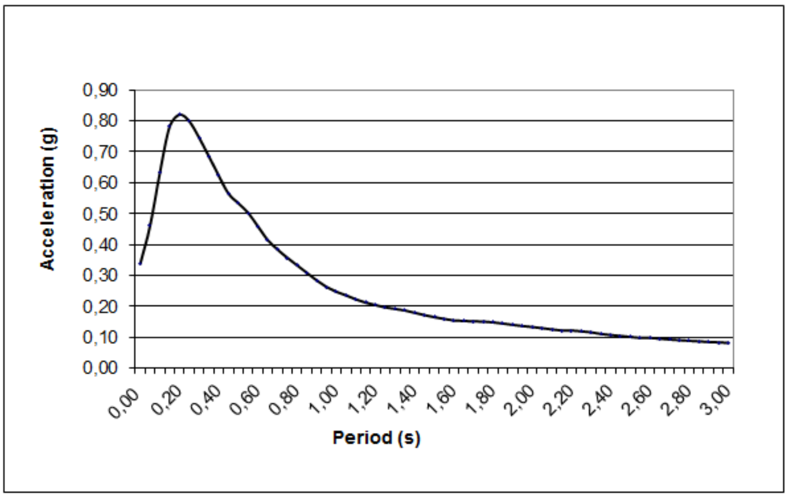

Figure 8b: Spectral Accceleration for M:6.8 and Vs30 > 350 m/s

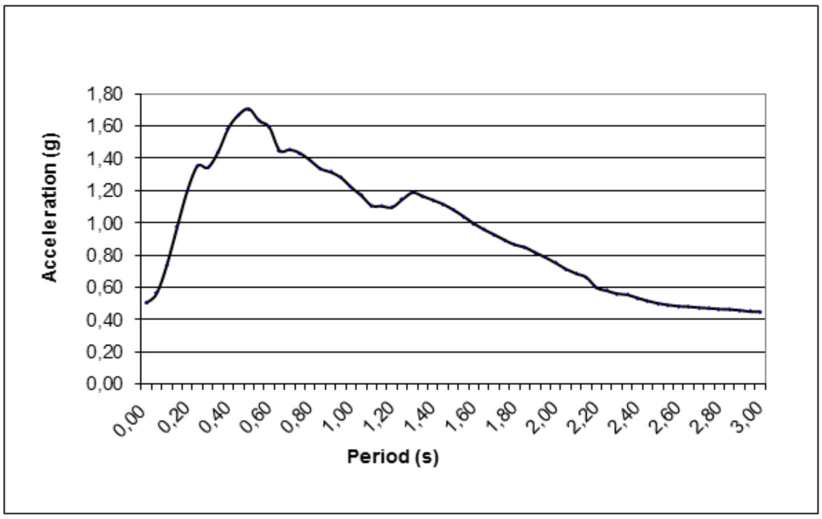

Figure 8c: Spectral Accceleration for M:7.6 and Vs30 < 350 m/s

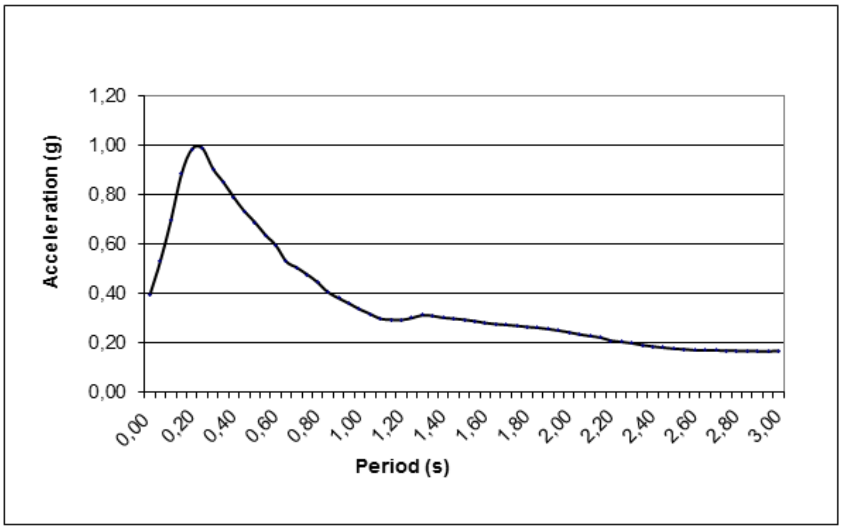

Figure 8d: Spectral Accceleration for M:7.6 and Vs30 > 350 m/s

Conclusion

Cultural Heritage are difened by ICOMOS (International Cultural Tourism Committee) as the ways of living developed by a community and passed on from generation to generation ,including customs, practices, places, objects, artistic expressions and values. Cultural Heritage could be divided as

- Built Environment
- Natural Environment
- Artefacts

There are several historical buildings on Büyükada, such as the Ayia Yorgi Church and Monastery dating back to the sixth century, the Ayios Dimitrios Church, and the Hamidiye Mosque built by Abdul Hamid II and Greek Orphanage, a huge wooden building etc.

During the historical periods, the Turkey and surrpounding areas were shaken by numerous earthquakes produced by main fault systems. As Bahnhoff (2013) pointed out there is a seismic gap (that has not been filled for 250 years) south of Istanbul and beneath the Marmara Sea [7]. This result based on the micro earthquakes recorded by seismographs primarily on the Princes Islands offshore Istanbul.

There are mostly 3-story buildings in Buyukada. Periods of these buildings are approximately 0.3 s. Building types of structures are masonry, concrete and wooden structres. Soil(site) periods are consistent with period of the buildings as a result of our work.

Turkish Earthquake Design Code has been used for the buildings since 2007. Buildings in the region are historical and constructed before this code regulations.

Earthquake risk may be increased due to the possible soil-earthquake interaction in Buyukada. For these reasons, a Earthquake Master Plan for this region must be carried out to mitigate the earthquake risk.

Acknowledgements

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