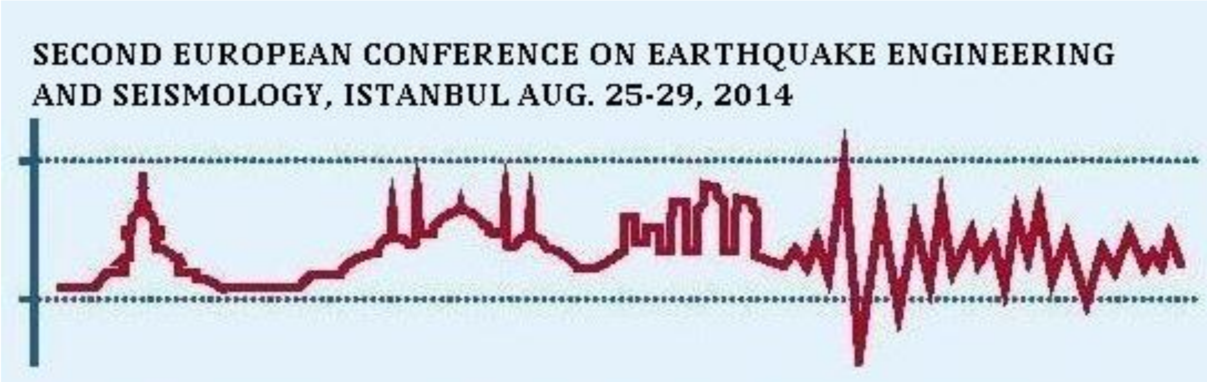

CYPRUS STRONG MOTION DATABASE: RESPONSE SPECTRA FOR SHORT RETURN PERIOD EVENTS IN CYPRUS

Ismail SAFKAN[1]

ABSTRACT

Cyprus experienced many destructive earthquakes through its history. However the development of strong motion networks on the island is rather recent. Earliest recordings started in late 90s and the database still lacks events with long return periods. In this paper, spectral characteristics of the strong motion data of 29 different events with moment magnitudes in the range 3.5-6 were analysed. Time domain characteristics of these records were assessed as well as their spectral properties.

It is noted by Grazier and Kalkan (2009) that for the smaller magnitude earthquakes, the maximum amplitude of normalized spectra is higher in comparison to that of bigger events. Currently, Turkish Earthquake Code 2007 (TEC2007) and Eurocode 8 are in use in Cyprus. Unlike to TEC2007, EC8 provides a separate acceleration spectra (Type 2) for the events with intensities less than Mw5.5. In this paper, we make comparisons between the normalized spectra suggested by TEC2007, EC8 Type 2 and the median observations which were developed based on the Cyprus ground motion database. The generated median spectra can be used for the purposes of generating fragility curves against the aftershocks in the Eastern Mediterranean region.

INTRODUCTION

The island of Cyprus had been hit by destructive earthquakes through its history. The early strong motion recordings for the island go back to late 90s (CGSD 2014). These records only cover intensities up to magnitude 6 which are considered as short return period events. But dangerous levels of ground shaking may still occur from short return period events when the epicentral distances are close (See Table 1).

In Cyprus, currently the modern seismic design codes such as Eurocode 8 and Turkish Earthquake code 2007 are in use. These codes provide specifications for design spectra and these design spectra were generated by considering wide range of events. This paper analyses spectral ordinates of the strong motion database in hand and also questions if the code specified acceleration spectras are appropriate for the short return period events in Cyprus.

[1] PhD Student, Eastern Mediterranean University, Famagusta, North Cyprus, ismail.safkan@cc.emu.edu.tr

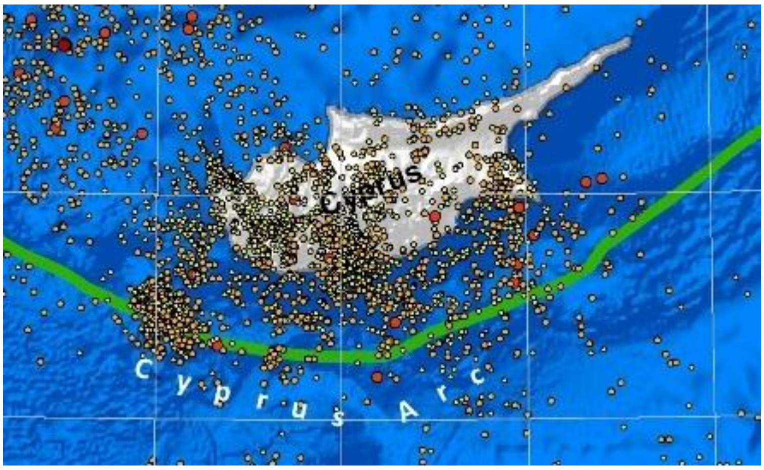

Figure 1. Seismicity and Active Fault line of Cyprus Island (CGSD 2014)

Figure 1 shows that seismicity is widely distributed on island and the probability of close epicentral distance event is high. In addition, it can be observed that the densities of the events are higher along the southern coastline of the island along the Cyprus Arc which is the main seismic source for Cyprus.

Strong motion networks in Cyprus became active in late 90s. However these stations did not function at the same period of time thus inaccuracy exists in the determination of soft soil amplification characteristics. Table 1 shows the location of ground motion stations of 3 different networks. First network was managed by Cyprus Geological Survey Department (CGSD) between 1997 and 2009 (CGSD 2013) however since 2009 it is not active. In 2007, Kandilli Observatory and Earthquake Research Institute set up 2 strong motion and 2 weak motion seismometer stations in the Northern part of the island. The final network was established in 2012 by the Middle East Technical University Northern Cyprus Campus also in the Northern part of the island., This network currently sends online data to METU-NCC and AFAD (Turkey Disaster and Emergency Ministry).

Table 1. Coordinates of ground motion stations (CGSD, AFAD, KANDILLI, 2013)

Cyprus Geological Survey Department (1997-2009)			North Cyprus Strong Motion Network Turkey Disaster Ministry (2013-2014)			KOERI Strong Motion Network (2007-2014)		
Name	Lat	Long	Name	Lat	Long	Name	Lat	Long
AHD	34.73	33.31	KT001	35.13	32.83	AKD	35.30	32.97
EVR	34.98	32.47	KT002	35.19	32.99	AKN	35.02	33.47
EMB1	34.82	32.43	KT003	35.25	33.02	LEF*	35.11	32.85
KPF3	34.76	32.42	KT004	35.39	32.95	ERN*	35.53	34.17
LMS	34.67	33.04	KT005	35.34	33.32	-	-	-
YER	34.74	33.09	KT006	35.35	33.6	-	-	-
LEF	34.85	33.36	KT007	35.53	34.18	-	-	-
DEK	34.98	33.75	KT008	35.17	33.91	-	-	-
LWP	34.70	33.00	KT009	35.13	33.93	-	-	-
PMP	34.65	33.01	KT010	35.04	33.71	-	-	-
PARA	35.04	33.98	KT011	35.22	33.42	-	-	-
CSS	34.96	33.33	KT012	35.18	33.37	-	-	-
PFA	34.72	32.49	KT013	35.21	33.32	-	-	-

*Weak Motion Broadband Seismometer

Soft soil conditions and epicentral distance also play an important role on ground motion characteristics (Kramer 1996). In order to take into account the epicentral distance differences and the soft soil amplification characteristics, data from all stations in hand are used in this study. Figure 2 shows the distribution of strong motion stations on the island.

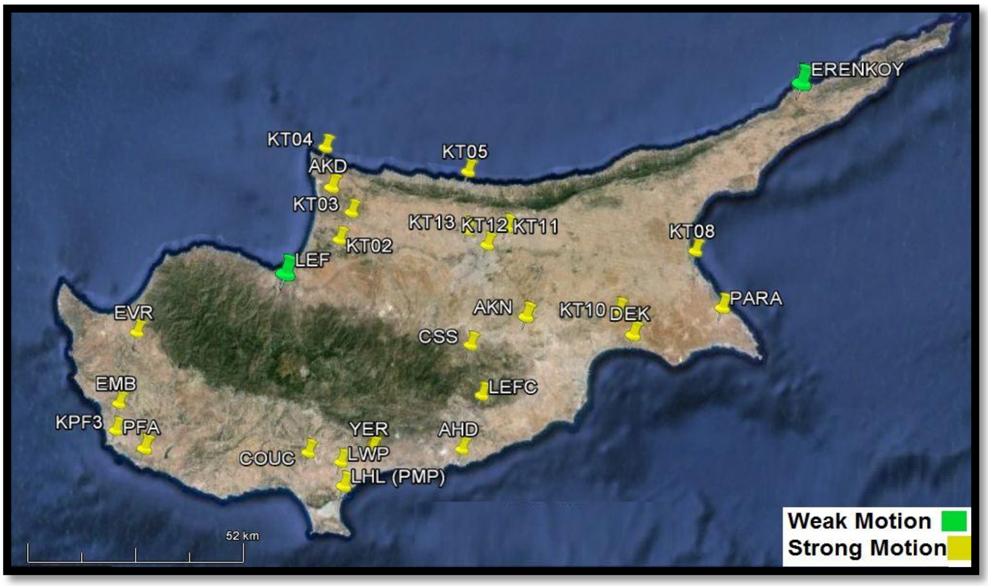

Figure 2. Locations of the Stations

Strong Ground Motion Catalogue

A total of 73 records from 29 events covering 17 years were analysed. The majority of the events are of shallow events (depth <30km). It can be seen from the table 2 that majority of the events have records with epicentral distances less than 50kM. Records with larger epicentral distances were deliberately excluded in this study as increasing the distance causes shifting of predominant period to higher values (Abrahamson and Silva 1997).

Table 2 Used events for generating a median 5% damped spectra.

Date	Latitude	Longitude	Ml	Depth (kM)	Nearest Record Distance (kM)	No of Records
13.01.1997	34.294	32.307	5.3	19	79	1
21.04.1998	34.883	33.007	4.2	5	23.9	1
25.05.1999	34.490	32.300	4.8	30	56.3	4
11.08.1999	34.750	33.030	5.2	12	5	3
13.08.1999	34.808	32.981	4.6	5	16.3	1
17.08.1999	34.826	32.998	4.4	5	17.8	1
26.08.1999	34.851	33.026	4.2	5	20.2	1
16.12.2000	33.574	33.358	4.3	30	125.3	1
25.10.2002	34.982	32.743	4.3	38	34.1	2
03.11.2003	34.700	33.060	4	10	3.8	4
18.05.2004	34.620	33.310	4	10	26	1
16.10.2004	34.431	33.286	4.5	30	10.2	5
12.01.2005	34.863	33.044	3.8	5	24.5	1
24.08.2005	34.810	32.970	3.6	15	12.5	1
29.09.2005	35.130	33.740	3.8	46	23.6	1
17.10.2005	34.850	32.970	3.6	10	16.9	1
15.10.2006	34.940	33.960	4.4	32	20.1	1
11.08.2007	34.778	32.293	3.6	30	190.3	1
28.08.2007	34.900	33.500	4.2	11	16.9	3
25.08.2009	34.740	33.090	4.6	31	13.1	4
16.09.2009	34.860	33.060	4.6	10	24.4	5
22.12.2009	35.910	31.430	5.4	25	154.2	4
11.05.2012	34.960	32.380	5.4	17	100.7	2
21.10.2013	34.960	32.380	3.6	20	45.7	2
23.10.2013	36.351	34.332	4.5	21	92.9	2
28.12.2013	35.987	31.342	6	42	167.6	3
03.02.2014	34.813	32.549	4.1	10.3	58.2	9
14.02.2014	36.750	36.040	4.5	15.7	215.8	4
06.03.2014	35.980	31.370	4.3	39.5	157.1	2
23.03.2014	34.620	33.39	3.8	19	74.1	2

ANALYSIS AND DISCUSSION

First of all, the digital ground motion data were processed by using the USDP software (Akkar et al. 2012). 4th order acausal filtering with 0.1 - 25 hz corner frequencies and baseline correction are considered for this study. The weak motion velocity data from LEF and EREN were differentiated and acceleration data were obtained.

As CGSD Stations do not function anymore, USGS provided Vs_{30} map is considered in order to group stations soil classes. On the other hand for the newly established METU NCC strong motion network, there had been a detailed site investigation prior to setting of stations. Lastly for the KOERI stations H/V method (Nakamura 1989) is used to estimate site period and corresponding soil class.

Once the filtering and soil classification is completed then the data is grouped according to the soil class and the average has been taken for rock and soil sites individually. The analysis is carried out by PGA normalising the average spectrums and then the amplification of peak spectral shape is observed even though the PGA amplification is avoided.

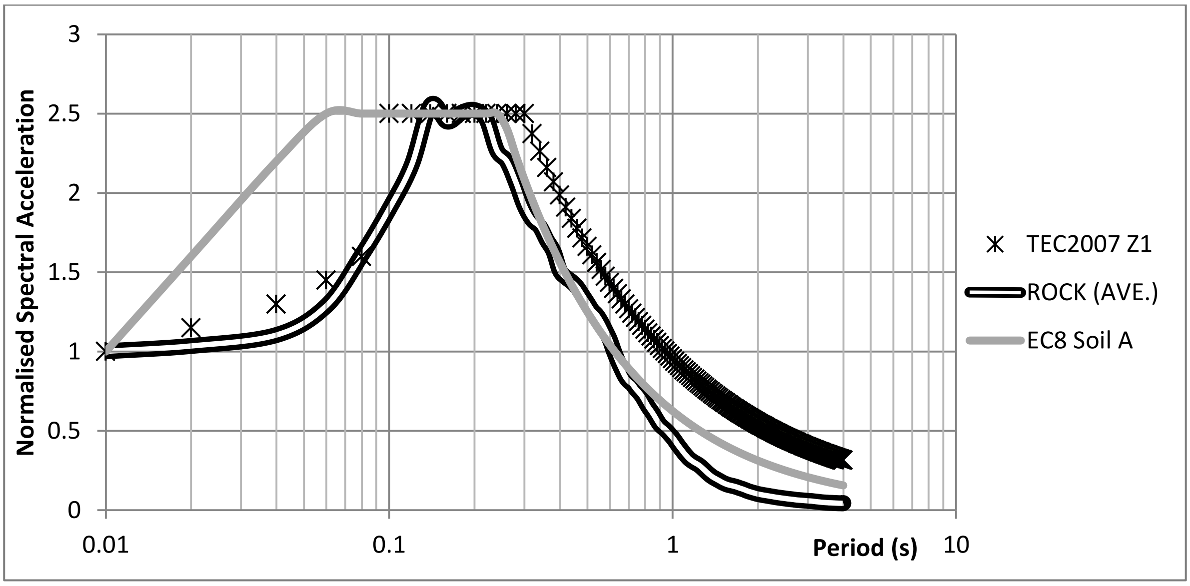

Figure 3. 5% Damped Acceleration Spectra for Rock Median Observations, Eurocode 8 Type 2 Soil and TEC 2007 Soil

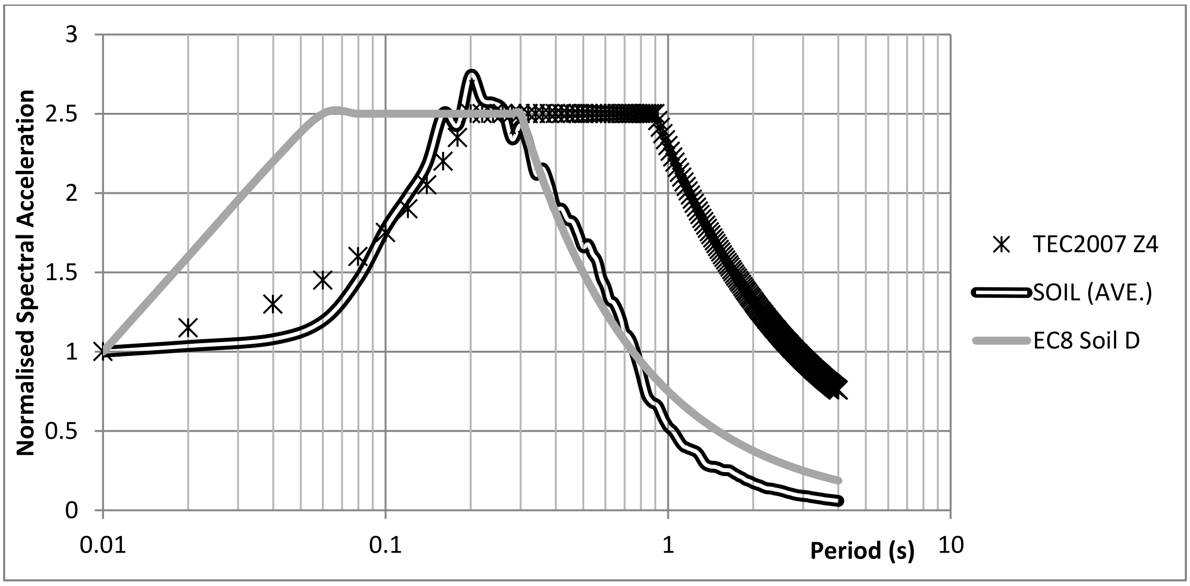

Figure 4. 5% Damped Acceleration Spectra for Rock Median Observations, Eurocode 8 Type 2 Soil and TEC 2007 Soil

Also the results indicate that (see fig 3 and fig 4), the EC8 supplies short return period spectra (Type 2) and TEC 2007 general spectra which underestimates the SA_{max} / PGA ratio at predominant period range. However the used data is still limited for deriving general empirical relationships for peak amplitude.

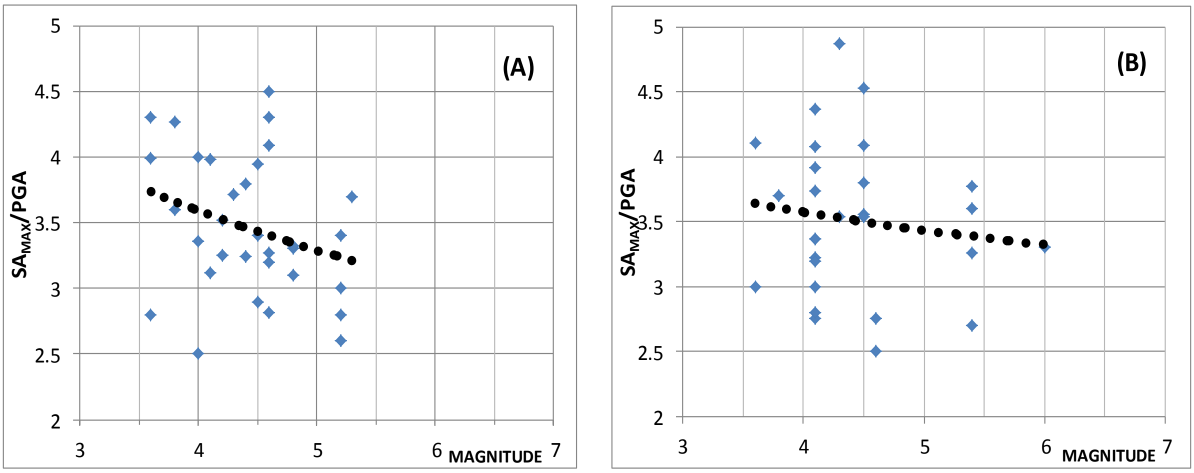

Figure 5. Maximum Spectral Acceleration to Peak Ground Acceleration Relationships A on left for Soil Conditions and B on right for Rock Conditions

Also EC 8 supplied short return period spectra (Type 2) represented a good fit to the median spectra when compared with the TEC 2007 spectra. This shows that TEC2007 should also include spectrum specifications for short return period events as TEC2007 overestimates the long period range for soft soil.

Increasing accuracy of the relationships that are given in figure 4, may pave the way for using magnitude specific (return period dependent) peak spectral acceleration coefficient for generating the target spectra in the future.

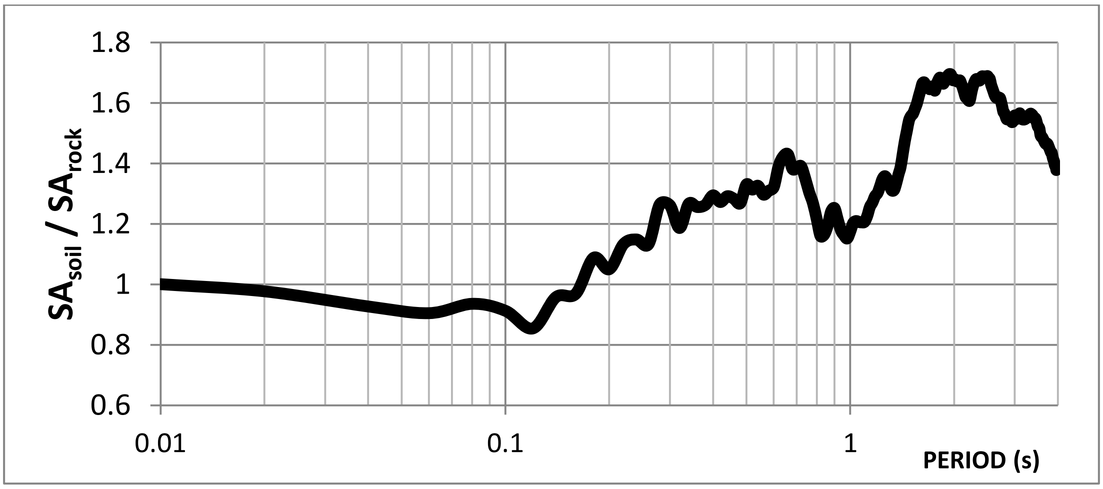

Figure 6. The Ratio of Spectral Acceleration on Soil to Spectral Acceleration on Rock

Subsequent to Figure 6 analysis, it can be seen that, up to period of 0.2 seconds, rock site shows higher amplitudes. On the other hand, as the soft soil conditions shift the predominant period of the events, the soft soil median spectra both shifts and increases. Table 3 compares the peak spectral acceleration ratio of recent studies and this research. This study shows higher SA_{max}/PGA ratios than those of recent studies since only low magnitudes are considered.

Table 3. Comparison of SA_{max} / PGA Ratio

	Edmund Booth For Major Events	Grazier and Kalkan (For Low Magnitude Events)	This Study (Low Magnitude, Rock)	This Study (Low Magnitude, Soil)
SA_{max}/PGA	2.65	2.60	2.55	2.75

CONCLUSIONS

To sum up, short return period events around Cyprus were analysed and the peak spectral acceleration ratio (peak SA/PGA) value for soil conditions was found to be higher than the current seismic design regulations. The peak SA/PGA ratio for rock site condition is determined as 2.55 and 2.75 for soil site conditions. Having obtained higher normalised SA/PGA ratio for soil and rock site, further research on generation of different peak spectral ratios for use with seismic design codes is needed. As Schott and Schwarz (2004) also proposed, instead of increasing the single soil factor value (as in Eurocode 8 which provided soil factors that require multiplication of the complete spectra), two separate soil parameters might be used for defining the soil amplification at peak spectral range and otherwise.

- Decrease in the peak spectral acceleration is obtained by increasing magnitude. The decrease of SA_{max} / PGA ratio had occurred for both soil and rock conditions for larger magnitudes.
- Implementation of short return period acceleration spectra to TEC2007 will avoid overestimation of spectral acceleration at long period range.
- Having the low magnitude event design spectra with high amplitude may result a difference compared to general response spectra if fragility assessment is carried out for aftershock events.

Acknowledgements
The authors would like to thank Cyprus Geological Survey Department for the Strong Motion Database and information on seismicity of Cyprus.

REFERENCES

Abrahamson, N. A., and Silva, W. J., 1997. “Empirical response spectral attenuation relations for shallow crustal earthquakes”, *Seismol. Res. Lett.* **68**, 94–127.

Akkar S., Ay Ö., Kale Ö. ve Pekcan O. (2012). Utility software for data processing (USDP), *http://www2.ce.metu.edu.tr/~sakkar/usdp.html*, son ulaşım 23.07.2012, Orta Doğu Teknik Üniversitesi, Ankara.

Booth E. (2007). “Estimation of Peak Ground Motion Parameters from Spectral Ordinates.*” Journal of Earthquake Engineering*. 11 pp.13-32

Cagnan Z. and Yilmaz M.T (2013). “Investigation of KKTC-NET Acceleration Record Characteristics.” *2nd Conference of Turkish Earthquake Engineering and Seismology*. Hatay. Turkey

Cagnan, Z., and G. B. Tanircan (2010). “Seismic Hazard Assessment for Cyprus.” *Journal of Seismology*, **14**, pp. 225-246.

CEN (2004) *Eurcode 8, design of structures for earthquake resistance-part 1: general rules, seismic actions and rules for buildings, EN 1998-1:2004*. Committee Europeen de Normalisation, Brussels

CEN (2007) *National Annex to Eurocode 8, design of structures for earthquake resistance-part 1: general rules, seismic actions and rules for buildings*, CYS EN 1998-1:2004. Committee European de Normalisation,Brussels

Cyprus Geological Survey Department (2013) Cyprus Strong Motion Database. Cyprus

Graizer V. and Kalkan E. (2009*)*. “Prediction of Spectral Acceleration Response Ordinates Based on PGA Attenuation”. *Earthquake Spectra* 1(25): 39-69

Kandilli Observatory (KOERI) (2014). Ground Motion Database. Online <http://udim.koeri.boun.edu.tr/>

Kramer S. (1996). Geotechnical Earthquake Engineering. Washington, Pearson

Nakamura, Y. (1989) “A method for dynamic characteristics estimation of subsurface using microtremor on the ground surface.” *Quaterly Report of the Railway Technical Research Institue* 30(1), 25-30

Schott C and Schwarz J (2004), "Reliability Of Eurocode 8 Spectra And The Problems Of Their Application To Central European Earthquake Regions. Paper: 3403**."** *13th World Conference on Earthquake Engineering.* Vancouver, Canada.

Seismosoft (2014). Seismosignal Ground Motion Processing Software. Online.

Turkish Republic Prime ministry, Disaster Management Department. (AFAD) (2013). *Turkish Strong Motion Database*. Online <http://www.deprem.gov.tr/>