AN ASSESSMENT OF THE RELATIONSHIP BETWEEN THE LOCAL SITE EFFECTS AND THE DISTRIBUTION OF DAMAGE IN THE CITY OF YALOVA (TURKEY) DURING 17 AUGUST 1999 İZMİT EARTHQUAKE.

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AN ASSESSMENT OF THE RELATIONSHIP BETWEEN THE LOCAL SITE EFFECTS AND THE DISTRIBUTION OF DAMAGE IN THE CITY OF YALOVA (TURKEY) DURING 17 AUGUST 1999 İZMİT EARTHQUAKE

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ABSTRACT

AN ASSESSMENT OF THE RELATIONSHIP BETWEEN THE LOCAL SITE EFFECTS AND THE DISTRIBUTION OF DAMAGE IN THE CITY OF YALOVA (TURKEY) DURING 17 AUGUST 1999 İZMİT EARTHQUAKE.

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The relationship between the local site effects and the damage distribution at the City Centre of Yalova after 1999 İzmit earthquake is investigated. The spatial distribution of building damage is presented by compiling the damage statistics reported after the event. It is observed that structural damage at the coastal areas and the ridges were limited. The most severe damage, however, was observed on Hacımehmet Basin and on the west side of Bağlarbaşı Quarter.

Peak ground acceleration during the earthquake is estimated by available ground motion estimation equations. Then, liquefaction evaluations are conducted for the available borehole data. It is concluded that, some deposits of the coastal areas with variable thickness have liquefaction potential. Finally, liquefaction potential map of the site in terms of liquefiable thickness is prepared. It is shown that the frequency of collapsed buildings near the boreholes with a liquefiable layer thicker than 2 m is limited. The relationship between the spatial distribution of collapsed buildings and the local site effects are investigated by one-dimensional non-linear site-response analyses, including response of liquefying layers. Idealized profiles are analysed with five selected and scaled ground motion records. The computed spectral accelerations and spectral amplification ratios are presented.

One-dimensional site-response simulations showed that the liquefaction can reduce the spectral amplitudes by a factor about 2.5 in the range of periods from 0.3 s to 0.4 s. This result is consistent with the observed building damage in the City. However, intensity of damage at Hacımehmet Plain cannot be explained with one-dimensional analyses. It is considered that two-dimensional response of the basin might have a prevalent contribution to the seismic demand in this area.

Keywords: Site response analysis, liquefaction, site-amplification, damage distribution

ÖZ

YEREL ZEMİN ETKİLERİNİN, 17 AĞUSTOS 1999 İZMİT DEPREMİ SONUCU YALOVA İLİ MERKEZİNDE MEYDANA GELEN HASAR DAĞILIMINA ETKİSİNİN ARAŞTIRILMASI.

İlhan, Cemal

Yüksek Lisans, İnşaat Mühendisliği Bölümü

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Bu çalışmada, yerel zemin etkilerinin, 17 Ağustos 1999 İzmit depremi sonucu Yalova İl Merkezinde meydana gelen hasar dağılımına etkisi araştırılmıştır. Deprem sonucu meydana gelen bina hasarının dağılımı, bina hasar istatistikleri işlenerek elde edilmiştir. Bunun sonucunda, kıyı bölgesinde sınırlı hasar gözlenirken, Hacımehmet Ovası ile Bağlarbaşı Mahallesinin batısında hasarın yoğunlaştığı görülmüştür.

Yer hareketi tahmin denklemleri kullanılarak, 1999 İzmit depremi için maksimum yer ivmesi tahmin edilmiştir. 1999 İzmit depremi parametreleri kullanılarak çalışma sahasında sıvılaşma potansiyeli değerlendirmiştir. Değerlendirmeler sonucunda, saha için sıvılaşma potansiyeli haritası hazırlanmıştır. Kıyı bölgesindeki kuyulardaki katmanların, farklı kalınlıklarda sıvılaşma potansiyeli olduğu, bunun dışında kalan alanlarda sıvılaşma potansiyeli bulunmadığı tespit edilmiştir. Hasar dağılımı ile sıvılaşma potansiyeli haritasının karşılaştırılması ile 2 m'den daha fazla kalınlıkta, sıvılaşan katman bulunan sondaj kuyularına yakın noktada bina hasarının olmadığı gözlenmiştir.

Hasar dağılımının yerel zemin etkileri ile ilişkisini açıklayabilmek için, sıvılaşma etkilerinin dâhil edildiği bir-boyutlu saha tepki analizleri gerçekleştirilmiştir. Bunun için sahanın idealize edilmiş zemin profilleri, seçilen ve ölçeklenen beş ayrı yer hareketi kaydı için analiz edilmiştir. Sonuçlar, her bir deprem kaydı için spektral ivme ve spektral ivme büyütmesi grafiği ile gösterilmiştir.

Bir-boyutlu saha tepkisi simülasyonları, sıvılaşmanın 0,3 s ile 0,4 s periyotları arasında spektral genliklerde 1/2,5 oranında azalmaya yol açabileceğini göstermiştir. Ancak Hacımehmet Ovası ile Bağlarbaşı Mahallesinin batısında gözlemlenen hasar yoğunluğu, bir boyutlu analizlerle açıklanamamaktadır. Burada iki boyutlu basen tepkisinin sismik talep üzerinde hakim bir katkısının olduğu düşünülmektedir.

Anahtar Kelimeler: Saha tepki analizi, sıvılaşma, zemin büyütmesi, hasar dağılımı

To My Family…

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TABLE OF CONTENTS

LIST OF FIGURES

FIGURES

LIST OF TABLES

TABLES

LIST OF SYMBOLS

a_{max}	Peak ground acceleration
c_1	Contraction parameter 1
c_2	Contraction parameter 2
C_B	Borehole diameter correction factor
C_E	Energy correction factor
C_N	Overburden pressure correction factor
C_R	Rod length correction factor
C_S	Sampling method correction factor
c_u	Undrained shear strength
CMSP	City Microzonation Survey Report - Base to Master Plan of 1150 Hectare Area of Yalova City (Sönmez Eng. Co., 2015)
CRR	Cyclic resistance ratio
CSR	Cyclic stress ratio
d_1	Dilation parameter 1
d_2	Dilation parameter 2
D_r	Relative density
f	Site dependent factor
$F_{inferred}$	Inferred shear wave velocity factor
F_{NM}	Normal faulting factor

F_{RV}	Reverse faulting factor
FC	Fines content
FS	Factor of safety
g	Gravitational acceleration
$GMPEs$	Ground motion prediction equations
GWL	Ground water level
h	Height
I_R	Length of rod
K_σ	High overburden pressure correction factor
K_α	Initial-shear correction factor
M_w	Moment magnitude
MSF	Magnitude scaling factor
N	Number of story
$(N_1)_{60}$	SPT blow count corrected for 60% efficiency and overburden pressure
$(N_1)_{60,CS}$	SPT blow count corrected for 60% efficiency, overburden pressure and fines content
N_{60}	SPT blow count corrected for 60% efficiency
N_i	0.5 times of field SPT blow count
N_m	Field STP blow count
P_a	Atmospheric pressure
PGA	Peak ground acceleration
r_d	Depth-dependent stress reduction coefficient
R_{JB}	Closest distance to surface projection of coseismic rupture

R_{RUP}	Closest distance to coseismic rupture
r_u	Pore pressure ratio
R_X	Horizontal distance from top of rupture measured perpendicular to fault strike
S_A	Site factor
S_S	Site factor
SPT	Standard Penetration Test
t	Thickness of liquefied layer
T	Period
u	Pore water pressure
V_S	Shear wave velocity
V_{S30}	Average shear wave velocity in top 30m of site profile
z	Depth
Z_{TOR}	Depth to top of coseismic rupture
α	Fines content correction coefficient
β	Fines content correction coefficient
γ	Unit weight
δ	Dip angle
σ_{vo}	Total overburden pressure
σ'_{vo}	Effective overburden pressure
ϕ	Angle of friction

CHAPTER 1

INTRODUCTION

Structural safety requires a challenging competition with natural disasters. Key of success lies in understanding the mechanisms of natural disasters and their consequences. Local site effects are one of these factors that can significantly affect seismic demand on structures.

A devastating earthquake occurred in 1999 due to rupture of a western segment of North Anatolian Fault. The earthquake caused severe damage in the City of Yalova. Spatial distribution of damage gave the impression that the local site effects might had significant impact at the Centre of City. The scope of this study is to investigate local site effects with particular emphasis on liquefaction. Understanding possible local site effects can help reduce effects of possible future earthquakes. Also, existing buildings might be assessed more effectively.

The studies in literature related with this study are outlined in Chapter 2. Site response mechanism and local site effects are summarised. Ground motion prediction equations used for prediction of ground-motion amplitudes at the site are briefly explained. Then, the definition of liquefaction phenomenon is given, and the effects of liquefaction on site response are outlined.

Chapter 3 covers geology and seismicity around the City of Yalova. Surface geology is explained with in-situ test results. Then, characteristics of 17 August 1999 İzmit Earthquake are given.

Chapter 4 describes the data from the damage survey after the event. The statistics are given with respect to quarters covered in the study area. As a result, spatial distribution of the damage is obtained.

Chapter 5 involves evaluations of liquefaction potential. The methodology of evaluation is outlined and estimation of peak ground acceleration is described. The liquefaction potential map of the City Centre is prepared.

Chapter 6 covers the site response analyses and results. Firstly, *Cyclic1D* software used in the site response analyses is introduced. Target acceleration spectra determination is presented. Idealized profiles used for the analyses are given. Ground motion selection and scaling procedure are explained. Results of analyses are presented.

Summary and discussion of the results are presented in Chapter 7. The conclusions and the suggested future works are presented in Chapter 8.

CHAPTER 2

LITERATURE SURVEY

2.1. Introduction

In this chapter, the literature related with the study is summarized. First, the site response mechanism and local site effects are presented. Second, ground motion prediction relationships (GMPEs) are briefly explained. Then, definition of liquefaction phenomenon is given with main parameters affecting liquefaction. Lastly, the effects of liquefaction on site response are discussed.

2.2. Site Response

Earthquake excitation is caused by rupture of a fault. Observed ground motion is dependent on the fault characteristics and the travel path of waves. However, the observed ground motion can be different – even on close sites. The reason of this variability is the differences in the local site conditions. This relationship is expressed in mathematical form by (Towhata, 2008),

$$R(x) = F(x) \cdot P(x) \cdot L(x) \tag{1.1}$$

where $R(x)$ represents a ground motion amplitude, $F(x)$ represents the fault mechanism effect, $P(x)$ represents the travel path effect, and $L(x)$ represents the local site effect. Local site effect is described by Srbulov (2008) as,

- The effect of local soil layers,
- The effect of basin edge,
- Topographical effects.

2.2.1. The Effect of Local Soil Layers

Local soil layers can effect seismic response due to impedance contrast between sediments. By considering horizontally continuous layers of soils, one-dimensional analyses can be conducted to estimate local site effects. (Ansal, 2004). Equivalent linear, and nonlinear analyses are possible methods. Cyclic1D software developed by Yang et al. (2015), used in this study, is among the computer programs for the effective-stress based site-response analysis.

2.2.2. The Effect of Basin Edge

Strong lateral geological discontinues, including basin edge, can affect seismic ground shaking. Two-dimensional or three-dimensional models representing horizontal variability in geological conditions are considered instead of a one-dimensional model (Ansal, 2004). The case studies involving basin edge effects are summarized as follows.

Bakır et al. (1995) studied Dinar Basin, Turkey during 1995 Dinar earthquake (M_w=5.9). One-dimensional and two-dimensional models were analysed in this study and the spectral responses from the two approaches were compared. It is concluded that there were a significant increase in spectral responses at the edges of the basin.

Kawase (1996) studied the Kobe Basin, in Japan during Hyogoken, Nambu earthquake and conducted two-dimensional models to explain severe damage. Different seismic waveforms originating from the basin effect are computed as a result.

Bielak et al. (1999) studied the response of Kirovakan Basin during the 1988 Armenian earthquake. The basin involves medium to stiff clay deposits. The width to depth ratio of the basin was about 5. Severe structural damage at the site cannot be explained with one-dimensional response model, and two-dimensional models are utilized in the study. Peak ground acceleration by using a two-dimensional model is 50% larger than that computed by one-dimensional model, which is 0.55 g.

2.2.3. Topographical Effects

Topographic features such as ridges, canyons and ground slopes can effect seismic ground shaking. These sites tend to oscillate differently from horizontally layered ground because of discontinuity on the sides (Srbulov, 2008).

Trifunac and Hudson (1971) reported the contribution of topographical effects on ground motion recorded on a number of ridges near to Pacoima Dam during the 1971 San Fernando earthquake. Nechtschein (1995) studied eleven seismic stations in Nice, France in order to investigate the topographical effects. As a result, significant amplifications are identified in the ground motion recorded at the ridge crests. Assimaki (2005) reported heavy damage due to topographic effects on the eastern bank of the Kifissos River canyon during 1999 Athens earthquake.

2.3. The Ground Motion Prediction Equations

Ground motion caused by earthquakes is unpredictable and unrepeatable (Srbulov, 2008). However, the empirical methods, called as attenuation relations or the ground motion prediction equations (GMPEs), are useful for estimation of the amplitudes of ground motion at a particular site, designated with $R(x)$ in Equation (1.1). GMPEs are statistical relationships bases on a strong ground motion database. Two attenuation relations available in literature are used in this study: First, Akkar and Bommer (2010), developed for Europe, the Mediterranean region, and the Middle East. Second, Chiou and Youngs (2008), one of widely used GMPEs.

2.4. Liquefaction

The definition of liquefaction can go back to *"spontaneous liquefaction"* term stated by Terzaghi and Peck (1948). This term describes strength loss of loose cohesionless soils because of disturbance. However, the term *"liquefaction"* was used for the first time by Mogami and Kubo (1953) to describe deformations of saturated cohesionless soils due to fast monotonic, transient and repeated motions.

Bearing capacity failures and floating of buried structures after in 1964 earthquakes of Niigata and Alaska made geotechnical engineers take liquefaction phenomenon into consideration. Thereafter, 1971 San Fernando earthquake took place. This event triggered a landslide at the upstream side of San Fernando dam. 80,000 people were evacuated due to a possible failure of the dam. Following this event, the studies related with liquefaction phenomenon accumulated (Idriss and Boulanger, 2008).

Liquefaction of soils close to ground surface can cause excessive tilt or settlement of buildings, and heavy damage on buildings sensitive to differential settlements. It may cause also floating of buried structures such as pipelines and other infrastructure systems. Also, lateral spreading, the excessive deformation of liquefied material towards a free boundary, may cause damages on structures such as marine facilities. Due to the complexity of liquefaction phenomenon, the simplified liquefaction evaluation procedures have been developed for free-field conditions by considering case histories, and by interpretation of laboratory tests. One of these procedures, suggested by Youd et al. (2001), used in this study.

In the literature, it is stated that the triggering of liquefaction mechanism can dramatically alter response of a soil layer during earthquake. The effects of liquefaction on site response is summarised at Section 2.4.3.

2.4.1. Definition of Liquefaction

Seed (1982) defined the liquefaction as *"If drainage is unable to occur, the tendency to decrease in volume results in an increase in pore-water pressure, and if the pore-water pressure builds up to the point at which it is equal to the overburden pressure, the effective stress becomes zero, the sand losses its strength completely, and it develops a liquefied state"*.

In the literature, liquefaction term covers two different cyclic softening mechanisms: the flow liquefaction and the cyclic mobility. Flow liquefaction is the consequence of the condition that shear strength of soil after onset of liquefaction is not enough to satisfy static equilibrium. The structure can attain large deformations as a result of static shear stress and cyclic loading. Cyclic mobility specifies the condition that static shear strength is smaller than shear strength of soil after liquefaction triggering, but further shearing due to transient loading can cause significant ground deformations (Kramer, 1996).

2.4.2. Parameters Affecting Liquefaction

Liquefaction is affected from properties of soil and ground motion. Fundamental parameters are given as follows.

- Magnitude of earthquake,
- Peak ground acceleration,
- Ground water level,
- Type of soil,
- Density of soil,
- Confining pressure.

A more detailed discussion of parameters affecting liquefaction is presented by Kramer (1996) and by Idris and Boulanger (2008). These parameters are related to the duration and amplitudes of ground motion. Consequently, magnitude of earthquake and peak ground acceleration (*PGA*) are the basic parameters used in analyses.

2.4.3. Effects of Liquefaction on Site Response

Shibata (1996) stated that, massive and extensive soil liquefaction occurred during 1995 Hyogokeen, Nambu earthquake on the reclaimed sites. However, residents on liquefied soil did not feel the severity of earthquake due to seismic isolation effect of liquefaction, because, excessive shear forces were not transferred to the structures.

Lopez (2002) studied three liquefied sites. The first is the Port Island site, liquefied during 1995 Kobe Earthquake. The second is the Wildlife Site which liquefied during 1987, Superstition Hills Earthquake. The third is the Treasure Island liquefied during 1989, Loma Pietà Earthquake. Acceleration records of both outcrop motion and the free-field for liquefied sites were available. The study depends on comparison of motions recorded on liquefied ground level and the results of one-dimensional equivalent-linear site response analysis. It is concluded that the free-field response for a range of periods was reduced noticeably.

Kokusho (2014) investigated seismic base isolation mechanism in terms of energy by conducting laboratory experiments on soil models where a liquefiable layer overlies on a non-liquefiable layer. This study concluded that liquefied layer de-amplifies waves by shortening of wave length and base isolation mechanism tends to be more effective by increasing liquefied layer thickness.

CHAPTER 3

GEOLOGY AND SEISMICITY OF YALOVA

3.1. Introduction

City of Yalova is located on the Armutlu Peninsula in Northwest of Anatolia, Turkey (Figure 3.1). The centre of the City is on the north of this peninsula and on the coast of Sea of Marmara. In this chapter, geology and seismicity of the city are summarized.

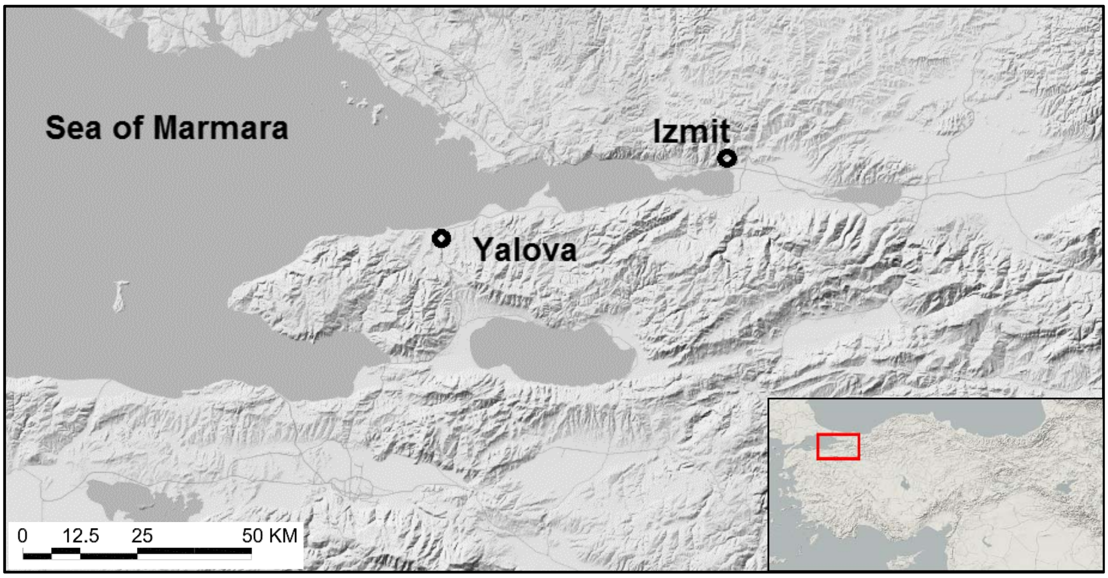

Figure 3.1: The City of Yalova map (World Terrain Map, 2015).

3.2. Geology of Yalova

City of Yalova is composed of two main geologic segments: Kılıç Formation and Quaternary deposits (Figure 3.2). There are ridges perpendicular to the Sea of Marmara formed by Kılıç formation. According to Akartuna (1968), this formation is as deep as 700 meters. This sedimentary formation consists of claystone, sandstone, siltstone, conglomerate and marl. Quaternary deposits consists of Holocene beach sediments, marine marginal plain, marine swamp sediments, flood plain sediments and Pleistocene sub-terrace sediments. They overlay wedges between the ridges and consist of varied grain sizes (Yılmaz and Yavuzer, 2005).

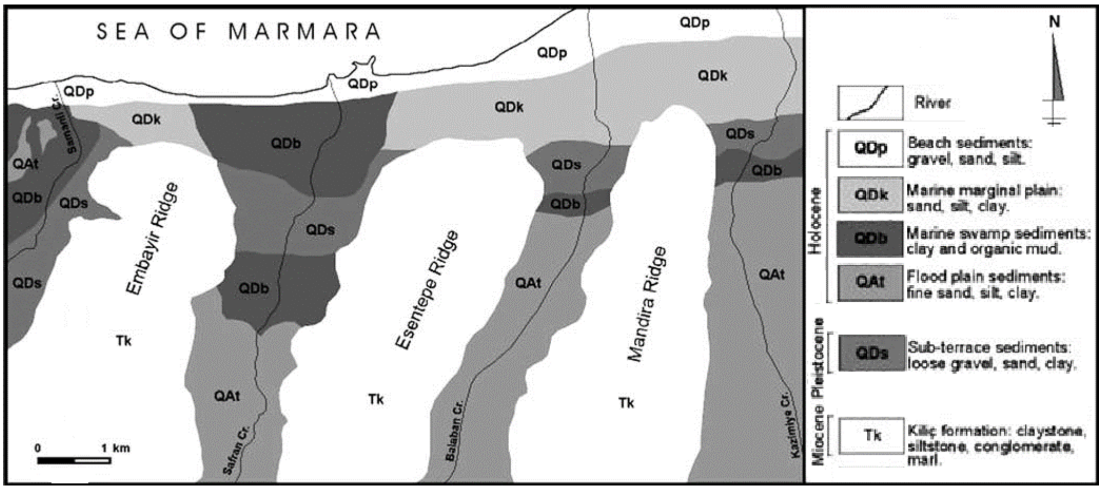

Figure 3.2: Geological map of the City of Yalova (Yılmaz and Yavuzer, 2005).

According to the City Microzonation Survey Report - Base to Master Plan Containing 1150 Hectare Area of Yalova City (2015) prepared by Sönmez Engineering Co. (hereafter refered as CMSP report), water table near coastal areas can seasonally reach to ground level at particular locations. Static ground water level map of the Centre of Yalova prepared by Yılmaz and Yavuzer (2005) is given in Figure 3.3. Ground water level measurements in several boreholes are given in tabular form in Appendix A. In addition to that, there are three rivers along the City of Yalova, named Safran, Balaban and Kazımiye.

Surface geology of the City of Yalova was studied within the scope of CMSP report with in-situ and laboratory tests. The limited sample in some locations such as Bahçelievler Quarter, were supplemented by the borehole data provided by Kendir (2010). Coordinates of the boreholes are presented in Appendix A. The locations of the boreholes are shown in Figure 3.4. The study area consists of altering soil profiles between close boreholes. The study area can be divided into zones considering geotechnical properties.

1. Shallow alluvial deposits around Bahçelievler and Rüstempaşa Quarters that are composed of loose to dense sand layers overlying Kılıç formation with shallow ground water.

2. Shallow stiff clay sites overlying Kılıç formation residuals and Kılıç formation on the west side of Kazım Karabekir and on the east side of Bağlarbaşı Quarter as well as the ridges of the study area.

3. Relatively deep and soft clayey alluvial deposits on the east side of Kazım Karabekir and on the west side of Bağlarbaşı Quarter overlaying Kılıç formation. This zone covers the Hacımehmet Plain and the Safran River. Ground water level is also shallow in this zone.

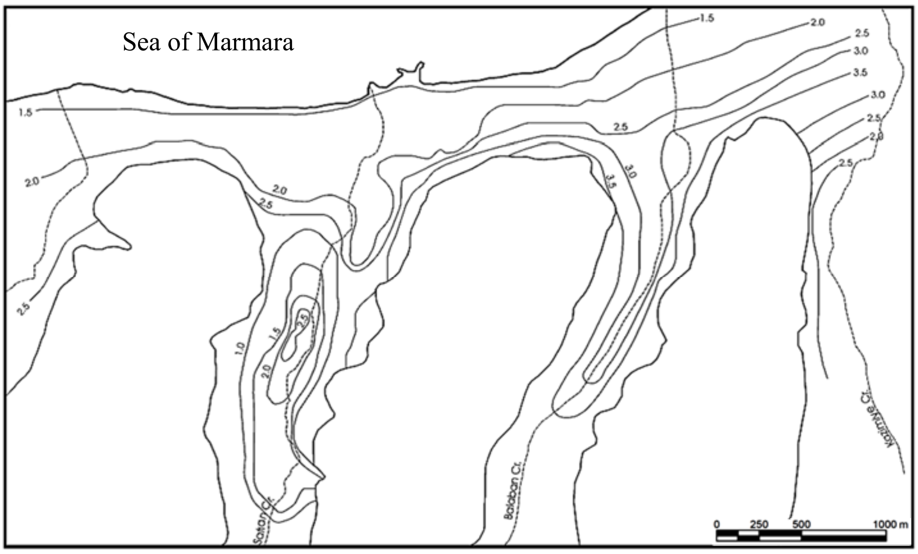

Figure 3.3: Static ground water level map of the City of Yalova. (Yılmaz and Yavuzer, 2005)

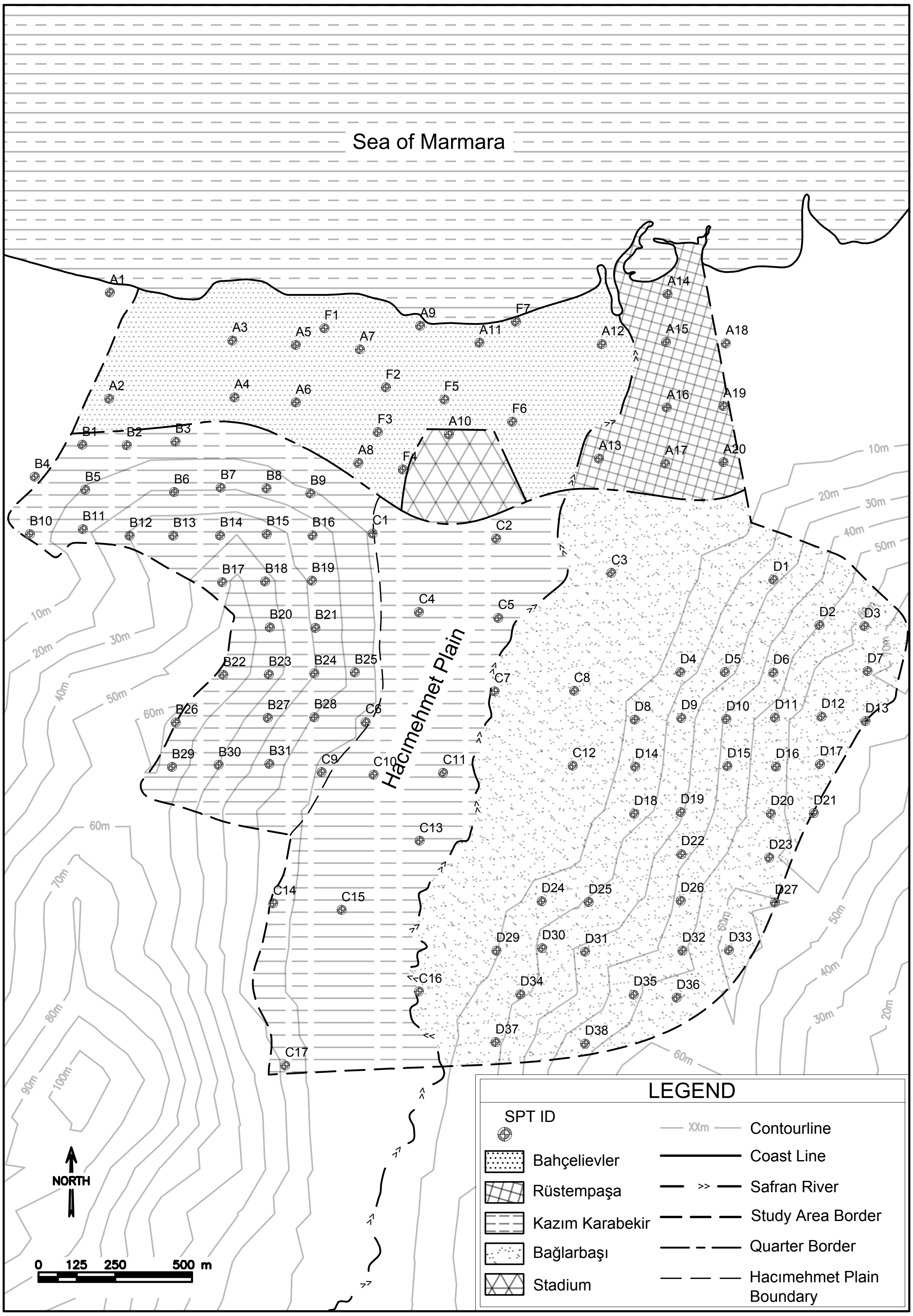

Figure 3.4: Map of the study area and the locations of boreholes.

3.3. Seismicity of Yalova

City of Yalova is located close to the North Anatolian Fault (NAF). The slip on this fault originates from the 20 to 30 mm annual displacement of Eurasian Plate relative to the Arabian Plate (Bohnhoff et al, 1999). The fault is approximately 1500 km long, and extends from eastern Anatolia to the Aegean Sea on the west. Its alignment is almost parallel to the northern part of the Country. The fault caused a series of significant earthquakes in the last century. They are shown in Figure 3.5.

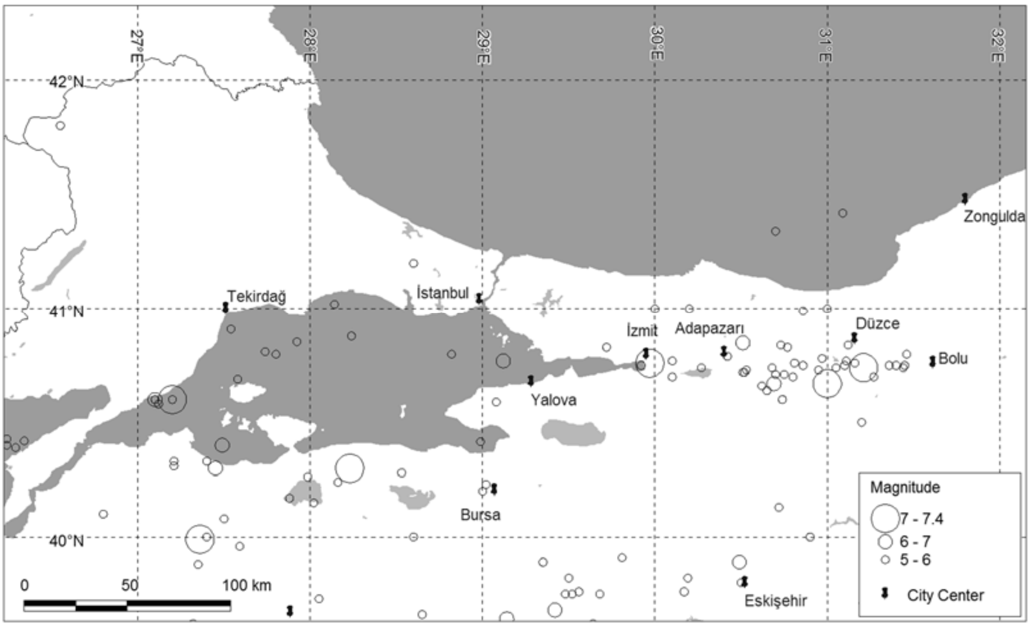

Figure 3.5: Seismic activity near the City of Yalova between the years 1901 and 2015 (UDIM, 2016).

The first event of the series was the 1939 Erzincan earthquake (M=7.9) on the east of the fault. The event sequentially followed by 1943, 1944, 1951 and 1967 earthquakes, indicating a movement towards the west of the country. The earlier 1912 rupture of a western segment of the fault, the Gallipoli segment, on the west of Sea of Marmara left the segments between west of the Sea of Marmara and Mudurnu stressed. A member of these segments successively ruptured during 17 August 1999 İzmit and 12 November 1999 Düzce earthquakes (Polat et al, 2002).

3.4. 1999 İzmit Earthquake

On 17 August 1999 at 03:02 (local time), western part of the North Anatolian Fault ruptured. According to the Boğazici University Kandilli Observatory and Earthquake Research Centre, epicentre of the earthquake coordinate was 40.77º N - 29.97ºE, and the moment magnitude (M_w) was 7.4. Its focal depth was 17 km. The right-lateral slip due to the earthquake was about 3 to 4 m along a significant length of the rupture (Erdik, 2001). A range of peak ground acceleration from 0.14 to 0.79 m/s^2 was obtained from the near-field strong motion stations settled on various site conditions (Anderson et al., 2000). Aschheim et al., (2000) stated that total number of collapsed/heavy damaged buildings was 86,585, and Kocaeli and Sakarya were the most affected cities from the earthquake. About three months later, this rupture was followed by 12 November 1999 Düzce Earthquake, rupturing the Düzce branch of the main fault, with a moment magnitude (M_w) of 7.2 (Erdik, 2001).

Eastern end of the İzmit earthquake rupture was determined by using surface deformations and slip offsets. However, the west end of the rupture was submerged. According to the ultra-high resolution bathymetry data, the west end of the rupture extents up to 29.24º East (6.9E+05 East in UTM coordinate system) (Uçarkuş et al., 2011). Hence, total length of the rupture was approximately 145 km. The rupture stroke parallel to the City Centre of Yalova and terminated on the north of the City (Figure 3.6). The nearest distance from fault rupture to the City Centre was about 8.5 km. Dip angle of the rupture was ranging from 82º to 90º (Bouchon et al., 2009; Sekiguchi et al., 2002; Delouis et al., 2002).

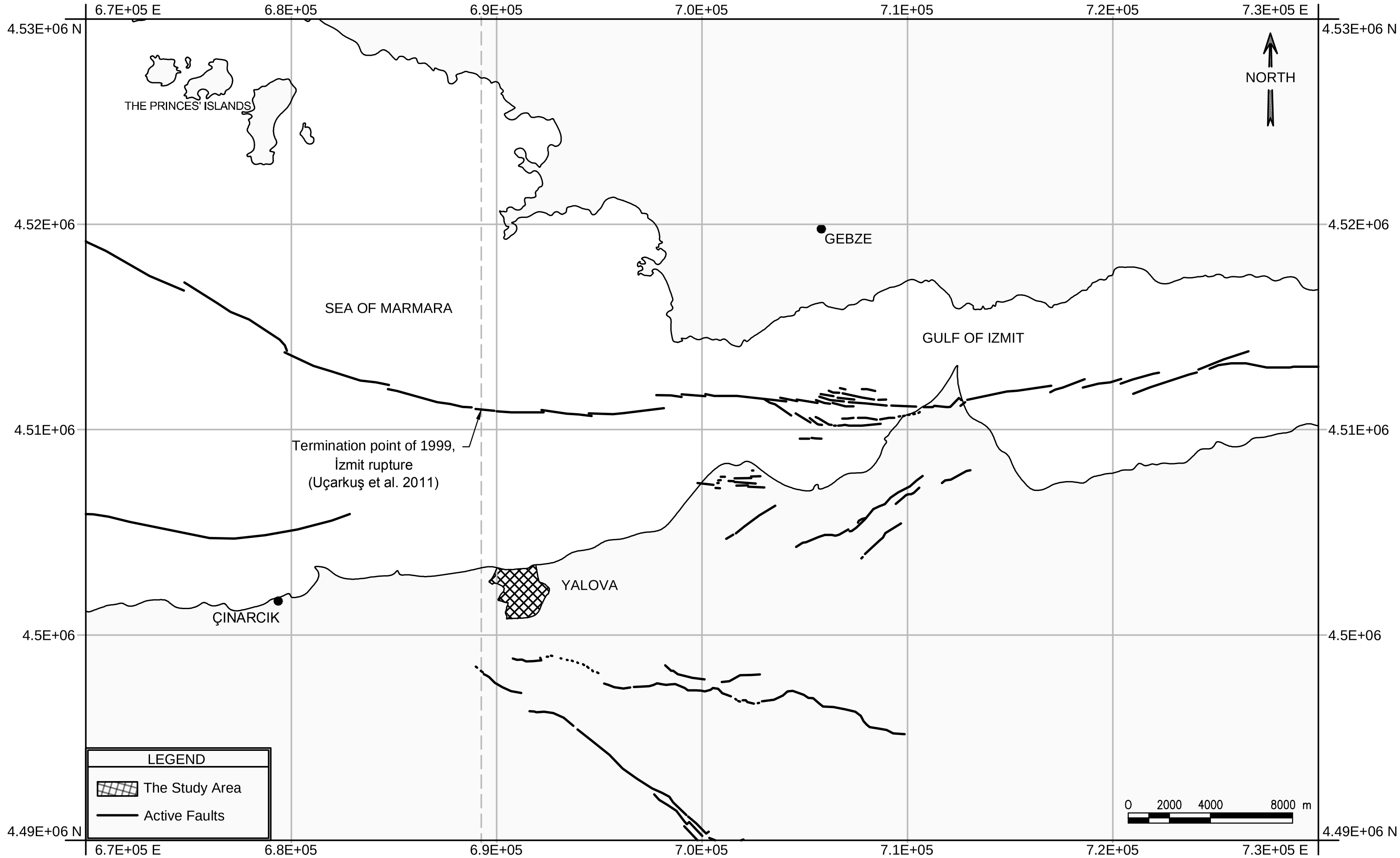

Figure 3.6: Active faults near the City of Yalova. (After Emre, Ö. 2011)

CHAPTER 4

DISTRIBUTION OF DAMAGE

4.1. Introduction

The effect of local site conditions on ground motion in the City of Yalova during 1999 İzmit Earthquake is investigated by adapting the methodology of Bakır et al. (2005). Hence, the statistics for structural damage were spatially compared with the local geological conditions.

In this chapter, the statistics for building-damage assessment reports provided by the Prime Ministry Disaster and Emergency Management Authority (AFAD) are presented. The procedure followed to process the data is summarized. The population statistics for life losses and for injured people are summarised. The statistics for the losses and the damage related with the earthquake are also given to illustrate severity of the event.

4.2. Losses Related with 1999 İzmit Earthquake

According to Özmen (2000), 1999 İzmit Earthquake had affected one fourth of the population in Turkey. Cities affected the most are İstanbul, İzmit, Sakarya, Bolu, Bursa, Eskişehir and Yalova according to this study. Two of these namely, İzmit and Sakarya are those where the most loss of lives occurred. Number of lives lost and their total percentages to the population in the cities are presented in Table 4.1. According to the population census results provided by the Turkish Statistics

Institute, total population of City of Yalova was 168,593 in 2000. Özmen (2000) also stated that, 497 injured people transferred from the neighbouring city towns have lost their lives at the host. This number is included in the total number of deceased, but excluded from the number of deceased in the hosting city. According to the Table 4.1, the City of Yalova is the third city, regarding the number of life losses.

Table 4.1: Statistics for life losses and injured people at cities after 1999 İzmit Earthquake. (Özmen, 2000)

Province	Life Losses	Life Loss Percentage	Injured People	Injured Percentage
İzmit	9476	54	19447	44
Sakarya	3890	22	7284	17
Yalova	2504	14	6042	14
Istanbul	454	3	7204	16
Bolu	271	2	1165	3
Bursa	10	0	2375	5
Eskişehir	33	0	375	1
Zonguldak	3	0	26	0
Tekirdağ	0	0	35	0
Total	**17479**	**100**	**43953**	**100**

The city of Yalova has 6 districts named as Yalova Centre, Altınova, Armutlu, Çınarcık, Çiftlikköy and Termal. Yalova Centre and Çiftlikköy are the most affected districts of the city. Number of life losses, number of destructed buildings and population at the time are given in Table 4.2 for districts of Yalova.

Table 4.2: Population of Yalova districts (Population statistics, 2000) and number of life losses and injured people in each district after 1999 İzmit Earthquake, (Özmen, 2000).

District	Population (Year, 2000)	Life Losses	Life Losses (%)	Injured People	Injured People (%)
Yalova Centre	86091	1450	1.68	3395	3.94
Altınova	22801	14	0.06	27	0.12
Armutlu	7858	0	0	0	0
Çınarcık	21650	672	3.10	2297	10.61
Çiftlikköy	24789	365	1.47	314	1.27
Termal	5404	3	0.06	9	0.17

4.3. Distribution of Building Damage at the Site of Study

Building damage information of the City Centre of Yalova is not available in required detail to correlate with the site response. The available data is provided by Kendir (2010) compiling damage records of Yalova Municipality. The details for the buildings are not reported, such as story height, type of structural system, and the number of undamaged buildings. The locations of the destructed buildings, however, are known. Hence, building damage assessment reports pertinent to the 1999 İzmit Earthquake provided by AFAD are processed to obtain the damage statistics with required detail.

Şengün, H. (2007) reported that, the damage survey for 334,000 buildings were compiled within 20 days by 1200 technical stuff of The Ministry of Public Works and Settlement – which had later abrogated. This dataset involves the information for commercial, residential and official buildings in the districts that suffered most severe damage. All of the building assessment reports had an excessive volume with the content consisting of initial damage assessment reports and re-evaluation reports due to objections to initial damage assessment reports. An example of initial assessment report is presented in Figure 4.1. These reports were used for the coordination of economical aids. The following properties for each building was compiled from the reports.

- Name of owner or leaser
- Address/Location
- Number of stories
- Structural system info
- Damage level code

In these reports, damage was classified into levels numbered from 0 to 8 as shown in Table 4.3. These damage codes used in this study are consistent with those listed in Table 4.3.

Table 4.3: Building damage codes in the assessment reports provided by AFAD.

Damage Code	Damage Level
0	No damage
2	Little damage
4	Moderate damage
6	High damage
8	Collapsed

The intermediate damage levels are described in Sönmez et al. (2011) as follows:

Little damage: There is either no damage in structural system or capillary cracks exists. There might be cracks in partition walls and some of them might overturned.

Moderate damage: Structural system is damaged noticeably. However, renovation and strengthening of damaged structural system is economically possible.

High damage: Most of the structural members are damaged. There is a permanent drift between stories. Renovation/strengthening of structural system is economically not possible.

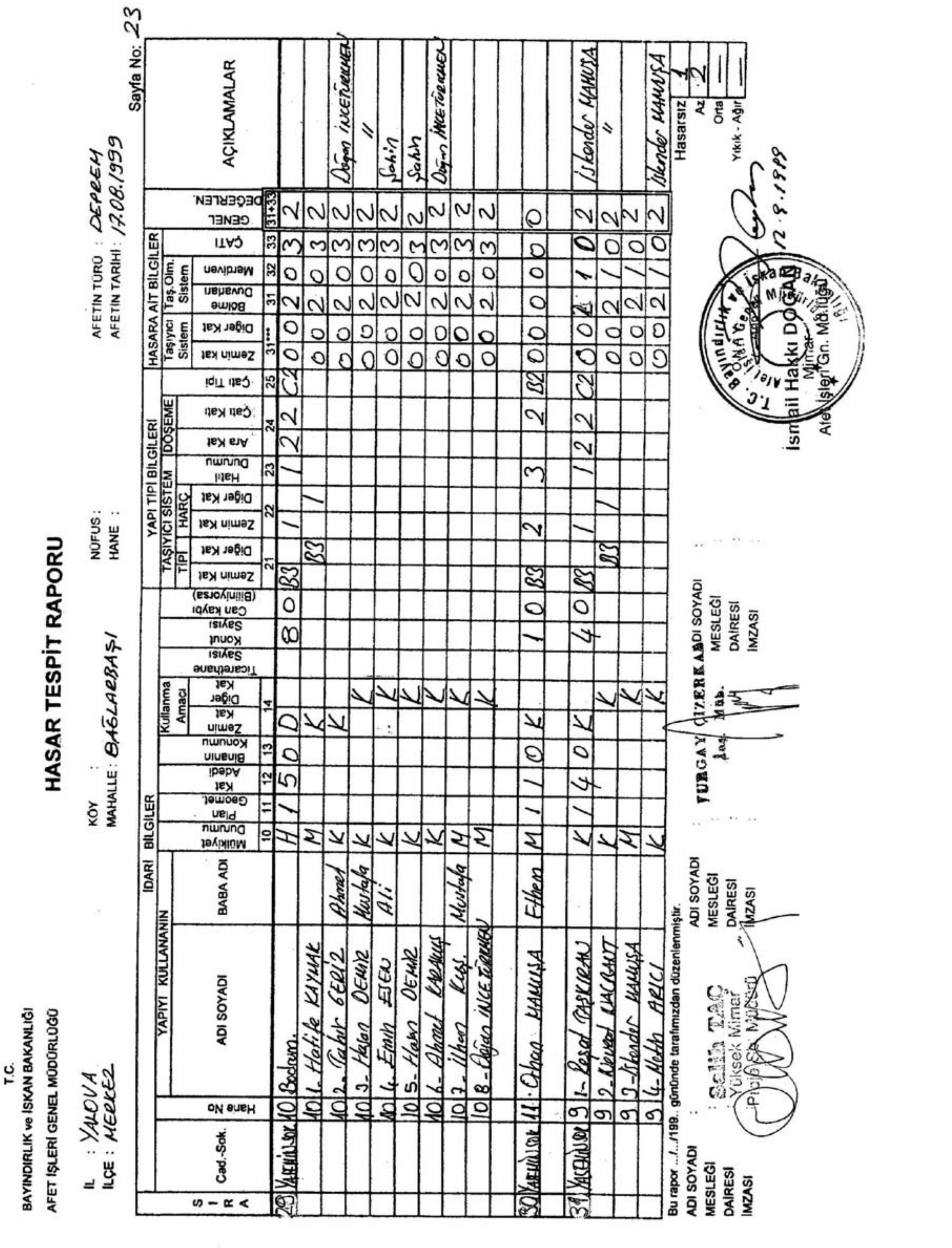

Figure 4.1: A sample page from processed building assesment reports.

Building damage assessment reports for five out of six quarters of Yalova Centre was available during the study. The assessment reports pertinent to Süleymanbey Quarter located in the east of Rüstempaşa Quarter had been prepared by two different technical teams and one of these teams incorrectly reported all the buildings as having one story. Therefore, Süleymanbey Quarter could not be considered in this study. Also, Stadium yard of Bahçelievler Quarter, where no building-type structure exists, is excluded from the study area. The resulting study area, given with Figure 3.4, comprises of these four quarters:

1. Bahçelievler
2. Rüstempaşa
3. Kazım Karabekir
4. Bağlarbaşı

Data of assessment reports are processed with filters and with some assumptions. They are listed below:

- Only the buildings having a reinforced concrete structural system that used for commercial, residential and official purposes are taken into account, so that the characteristic properties of structural response are reasonably predictable.
- A reinforced concrete building under construction is taken into account in the case that the structural system is completed.
- Re-evaluation reports that were prepared as a result of objections to initial assessment reports are also taken into account for the final damage level of buildings.
- In order to prevent duplicates, each building is associated with an owner, or a leaser, and also with an address. A few duplicate entries are eliminated.
- A few of the assessment reports which involved possible typing error in data are eliminated.
- The distribution of collapsed buildings on the streets of four quarters presented in Figure 4.2. The bars on this map are pointing at the centres of

streets determined by using Google Maps (2015) and Yandex Maps (2015). Some street names have been changed since the dates of issue of the reports. In order to locate former street names, the city plans of 1995 provided by the Municipality of Yalova are used. A few streets whose locations are not ascertainable are excluded from the map.

A sample of size arising from 2478 buildings is compiled as a result of this data processing. The number and distribution of buildings given in the assessment reports are reasonably consistent with the settlement density in year 1999. The details of damage survey are presented by tables and plots in the following sections of this chapter.

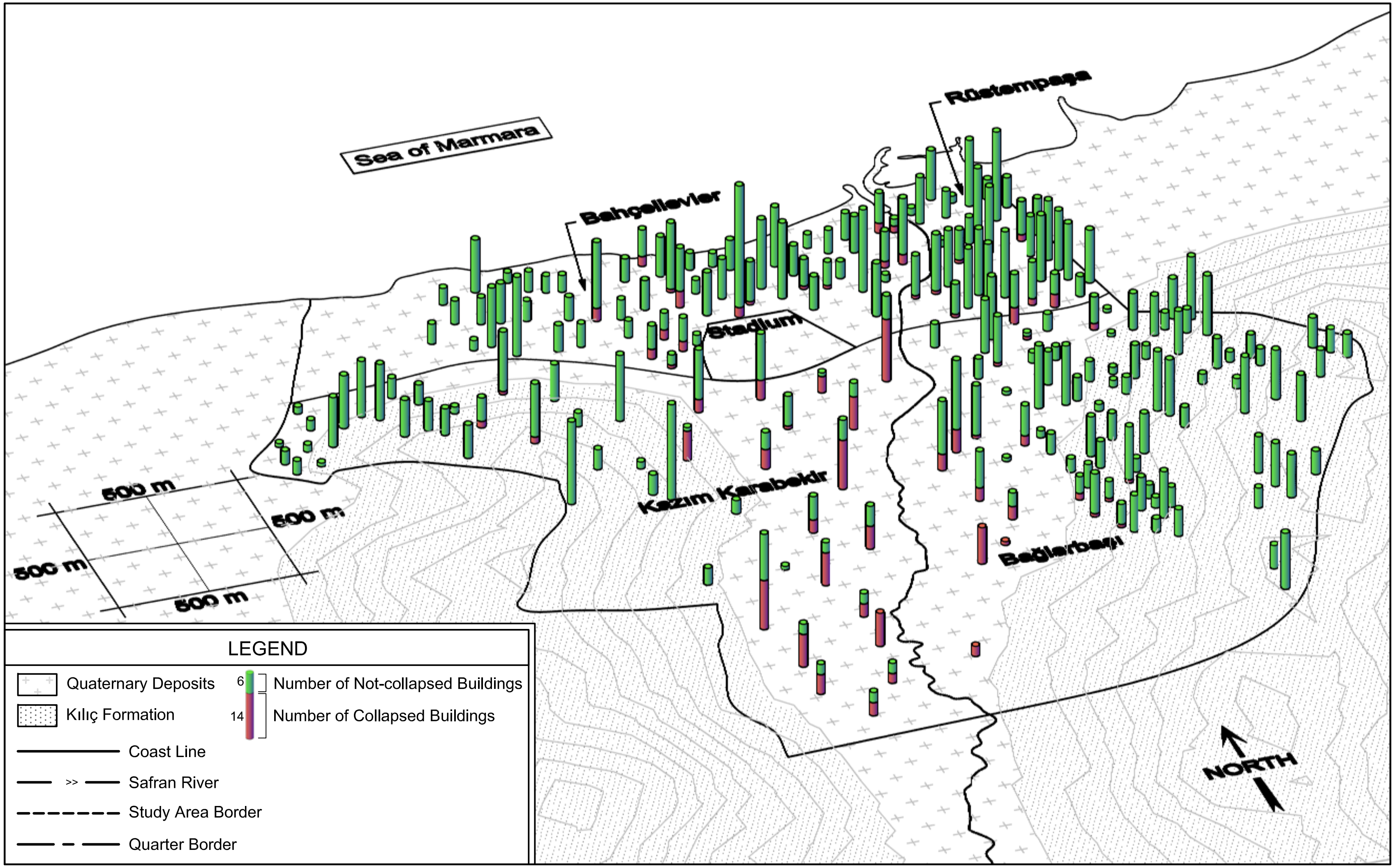

Figure 4.2: The map of damage distribution.

4.3.1. Building Damage in Bahçelievler Quarter

Bahçelievler Quarter is to the north of Yalova Centre District, and it is located on the Sea of Marmara coast. Here, the building damage was limited with respect to the other three quarters. Total number of reinforced concrete buildings counted in Bahçelievler was 664. The majority of the buildings located in this quarter have 3 to 6 stories. The relationship between number of stories and the damage code is presented in Table 4.4 and Table 4.5. The relative distribution of damage levels among story numbers are presented in Figure 4.3.

Table 4.4: Number of buildings among number of stories and the damage codes in Bahçelievler Quarter.

Damage Code	Number of Stories								
	1	2	3	4	5	6	7	8	9
0	2	14	31	81	32	26	1	0	1
2	0	6	25	112	82	62	4	3	0
4	0	0	2	35	26	34	1	0	0
6	1	0	3	26	19	4	3	0	0
8	0	2	3	18	12	4	1	0	0
Total	**3**	**22**	**64**	**272**	**171**	**130**	**10**	**3**	**1**

Table 4.5: Percentage of buildings among number of stories and the damage codes in Bahçelievler Quarter.

Damage Code	Number of Stories								
	1	2	3	4	5	6	7	8	9
0	0.3	2.1	4.6	12.0	4.7	3.8	0.1	-	0.1
2	-	0.9	3.7	16.6	12.1	9.2	0.6	0.4	-
4	-	-	0.3	5.2	3.8	5.0	0.1	-	-
6	0.1	-	0.4	3.8	2.8	0.6	0.4	-	-
8	-	0.3	0.4	2.7	1.8	0.6	0.1	-	-

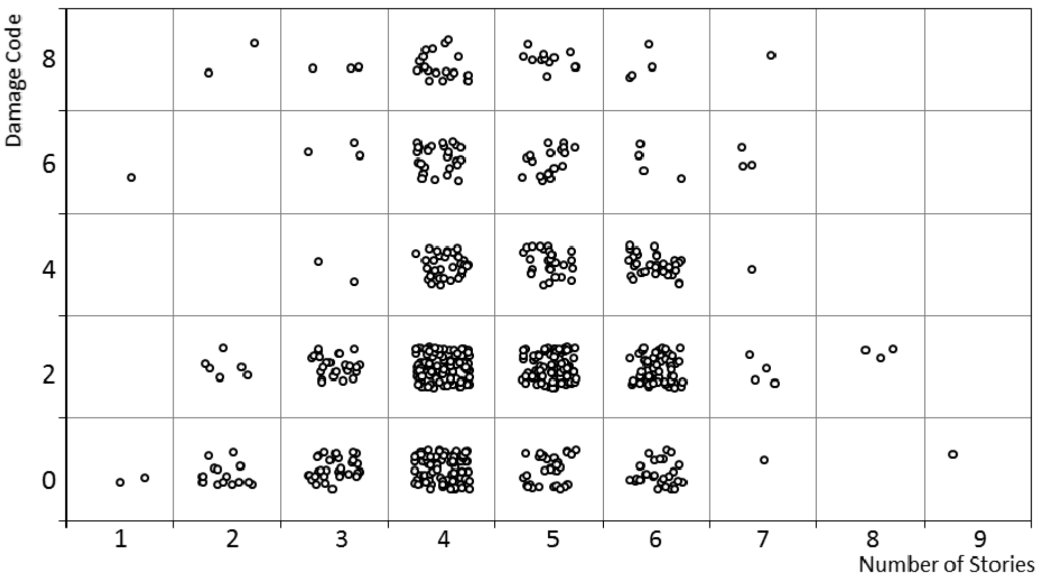

Figure 4.3: Distribution of damage levels versus number of stories for buildings in Bahçelievler Quarter.

4.3.2. Building Damage in Rüstempaşa Quarter

Rüstempaşa Quarter is to the north east of Yalova Centre District, and it is located on the Sea of Marmara coast. Similar to Bahçelievler, the damage in Rüstempaşa is also limited. The majority of the collapsed buildings are located on the south of the district, just near the border of Bağlarbaşı Quarter. Total number of buildings in Rüstempaşa was 444. The majority of the buildings in this quarter have 3 to 6 stories. The details are given in Table 4.6 and Table 4.7. The relative distribution of damage levels among story numbers are presented in Figure 4.3.

Table 4.6: Number of buildings among number of stories and the damage codes in Rüstempaşa Quarter.

Damage Code	Number of Stories						
	1	2	3	4	5	6	7
0	3	17	45	151	57	26	3
2	0	1	10	41	28	15	0
4	0	0	3	9	8	6	0
6	0	0	0	1	3	5	0
8	0	0	1	2	6	3	0
Total	**3**	**18**	**59**	**204**	**102**	**55**	**3**

Table 4.7: Percentage of buildings among number of stories and the damage codes in Rüstempaşa Quarter.

Damage Code	Number of Stories						
	1	2	3	4	5	6	7
0	0.7	3.8	10.1	34.0	12.8	5.9	0.7
2	-	0.2	2.3	9.2	6.3	3.4	-
4	-	-	0.7	2.0	1.8	1.4	-
6	-	-	-	0.2	0.7	1.1	-
8	-	-	0.2	0.5	1.4	0.7	-

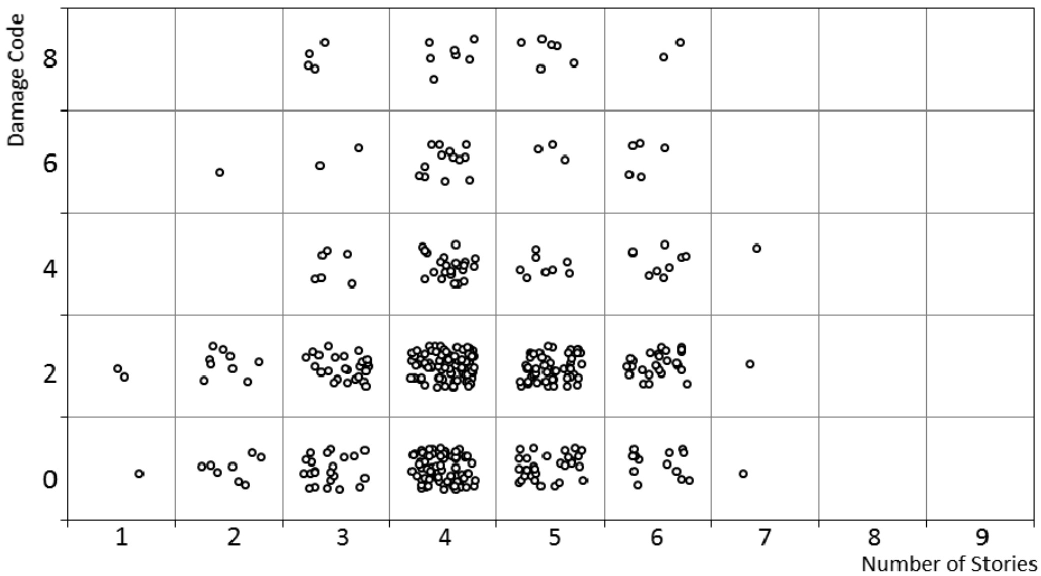

Figure 4.4: Distribution of damage levels versus number of stories for buildings in Rüstempaşa Quarter.

4.3.3. Building Damage in Kazım Karabekir Quarter

Total number of buildings in Kazım Karabekir was 536. The relationship between number of stories and the damage code is presented in Table 4.8 and Table 4.9. The relative distribution of damage levels among story numbers are presented in Figure 4.5.

Kazım Karabekir Quarter encloses a large area from the Safran River to the west of the city (at the time of the earthquake). Although, it was a recently settled area at the time of the earthquake, the eastern section of this quarter which is called Hacımehmet Plain was severely affected from the earthquake. The majority of buildings at this location have 4 to 6 stories. On the other hand, most of the buildings had 1 to 3 stories at the west of Hacımehmet Plain and the damage on these buildings were limited.

Table 4.8: Number of buildings among number of stories and the damage codes in Kazım Karabekir Quarter.

Damage Code	Number of Stories					
	1	2	3	4	5	6
0	26	84	67	8	12	1
2	20	40	25	13	7	0
4	4	6	11	9	31	1
6	1	1	1	3	25	6
8	0	0	7	15	105	7
Total	**51**	**131**	**111**	**48**	**180**	**15**

Table 4.9: Percentage of buildings among number of stories and the damage codes in Kazım Karabekir Quarter.

Damage Code	Number of Stories					
	1	2	3	4	5	6
0	4.9	15.7	12.5	1.5	2.2	0.2
2	3.7	7.5	4.7	2.4	1.3	0.0
4	0.7	1.1	2.1	1.7	5.8	0.2
6	0.2	0.2	0.2	0.6	4.7	1.1
8	0.0	0.0	1.3	2.8	19.6	1.3

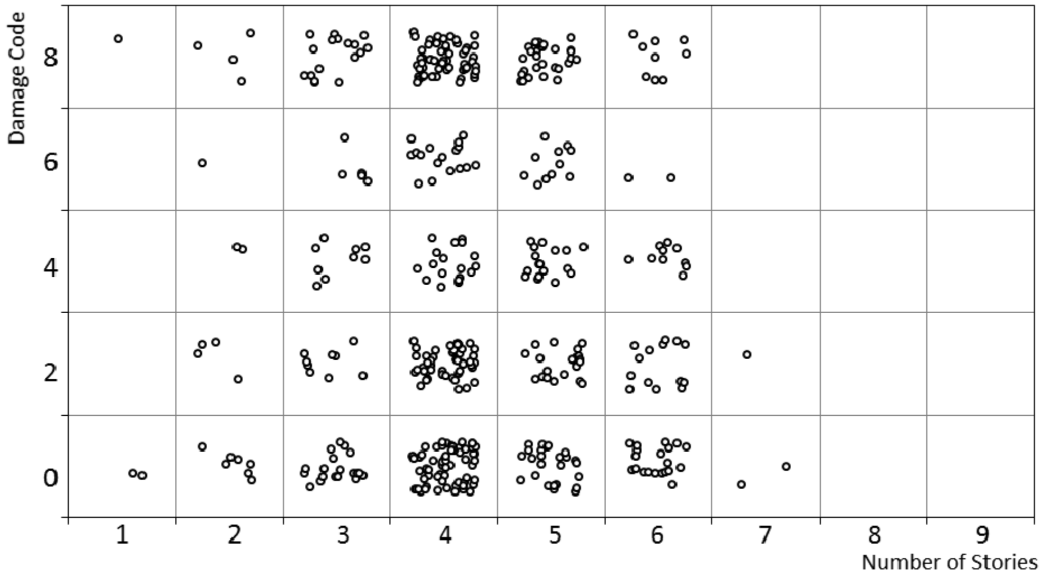

Figure 4.5: Distribution of damage levels versus number of stories for buildings in Kazım Karabekir Quarter.

4.3.4. Building Damage in Bağlarbaşı Quarter

Total number of buildings in Bağlarbaşı Quarter was 810. Most of the buildings had 1 to 4 stories. Building damage is moderate in this quarter and the majority of collapses were located near Safran River. The relationship between the number of stories and the damage code is presented in Table 4.10 and Table 4.11. The relative distribution of damage levels among story numbers are presented in Figure 4.6.

Table 4.10: Number of buildings among number of stories and the damage codes in Bağlarbaşı Quarter.

Damage Code	Number of Stories						
	1	2	3	4	5	6	7
0	152	177	118	53	14	1	0
2	19	62	45	28	8	1	0
4	4	8	19	17	14	1	2
6	0	1	6	16	6	6	0
8	0	0	2	16	19	6	1
Total	**175**	**248**	**190**	**130**	**61**	**15**	**3**

Table 4.11: Percentage of buildings among number of stories and the damage codes in Bağlarbaşı Quarter.

Damage Code	Number of Stories						
	1	2	3	4	5	6	7
0	18.5	21.5	14.4	6.4	1.7	0.1	0.0
2	2.3	7.5	5.5	3.4	1.0	0.1	0.0
4	0.5	1.0	2.3	2.1	1.7	0.1	0.2
6	0.0	0.1	0.7	1.9	0.7	0.7	0.0
8	0.0	0.0	0.2	1.9	2.3	0.7	0.1

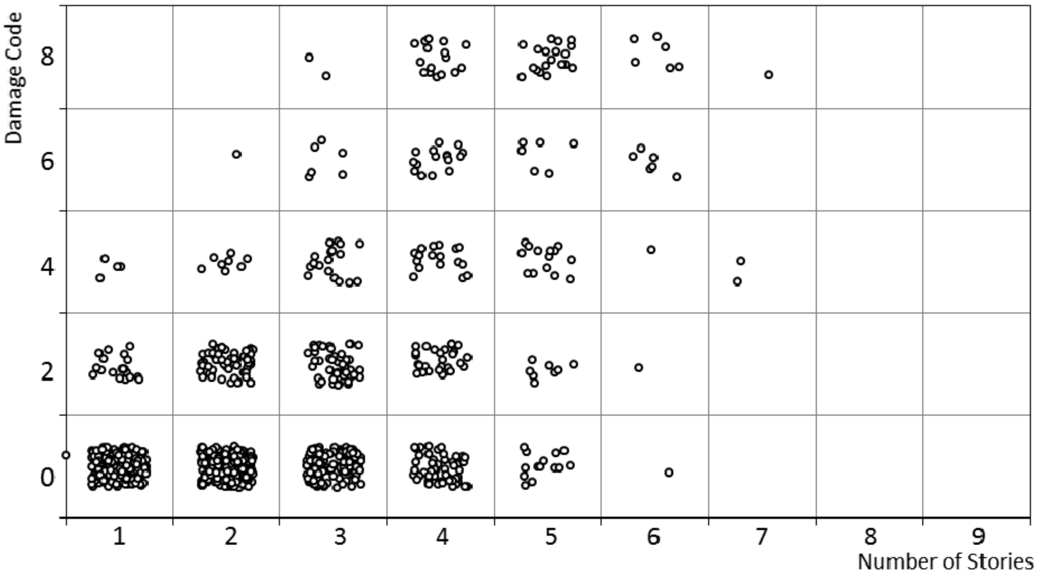

Figure 4.6: Distribution of damage levels versus number of stories for buildings in Bağlarbaşı Quarter.

CHAPTER 5

LIQUEFACTION EVALUATION

5.1. Introduction

The coastal area at the study site involves sand deposits. These deposits are considered as susceptible to liquefaction due to their density and due to high ground water level in the vicinity. It is discussed in Chapter 2 that liquefaction have significant effects on the site response. In this chapter, liquefaction resistance of the susceptible soils of the City Centre of Yalova are evaluated for 1999 Izmit earthquake with an analysis procedure summarised in Section 5.2. In addition, Section 5.3 summarises the estimation of peak ground acceleration at the site during the earthquake, which is a principal parameter used in estimation of liquefaction potential. Because of the lack of records of the earthquake at the site, the available ground-motion prediction relationships in literature are used. The assessments of liquefaction potential are summarised at the end of this chapter.

5.2. Liquefaction Resistance Evaluation Procedure

The alluvial deposits susceptible to liquefaction are identified according to the SPT procedure suggested by Youd et al. (2001), and relationship provided by the procedure is given with Figure 5.1. It is based on simplified procedure developed by Seed and Idriss (1971). It requires determination of two parameters, namely the Cyclic Stress Ratio (*CSR*) and the Cyclic Resistance Ratio (*CRR*).

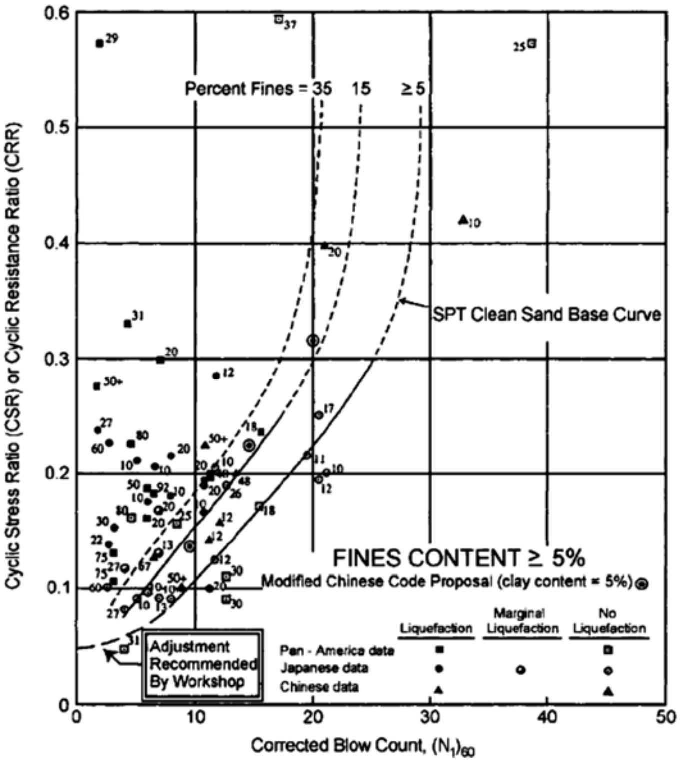

Figure 5.1: Relationship between SPT blow-counts and liquefaction case histories (Youd et al., 2001).

CSR and *CRR* are used for calculation of safety factor against liquefaction (*FS*) with contribution of correction factors such as earthquake magnitude correction factor (*MSF*), high overburden pressure correction factor (K_σ) and initial-shear correction factor (K_α), which is particularly necessary for steep slopes. K_α is not applied here due to low degree of slopes of the site. Only saturated sands are supposed to be liquefiable. A layer is supposed to have liquefaction potential, if *FS* is less than 1.0. Hence,

$$FS = (CRR_{7.5} / CSR) \cdot MSF \cdot K_\sigma \cdot K_\alpha \tag{5.1}$$

Seismic demand on a soil layer is expressed by Cyclic Stress Ratio (*CSR)* defined as (Seed and Idriss, 1971),

$$CSR = 0.65 \cdot (a_{\max} / g) \cdot (\sigma_{vo} / \sigma'_{vo}) \cdot r_d \tag{5.2}$$

where a_{max} is peak ground acceleration; g is gravitational acceleration; σ_{vo} denotes total overburden pressure, σ'_{vo} denotes effective overburden pressure, and r_d denotes a depth-dependent stress reduction coefficient. For simplification in analyses, it is assumed that the wet and saturated unit weights of the shallow deposits are equal. Hence,

$$\sigma_{vo} = \gamma \cdot h \tag{5.3}$$

where γ is the soil unit weight. The error due to this assumption is limited with respect to other sources of uncertainty. The effective overburden pressure is calculated by,

$$\sigma'_{vo} = \sigma_{vo} - u \tag{5.4}$$

where u is pore water pressure. Soil unit weight is assumed 18 kN/m³, when laboratory test results are not available for a specific layer.

Cyclic stress determination by Equation (5.2) depends on rigid soil column idealization. In order to take deformability of soil column behaviour into account, CSR should be corrected by the depth-dependent stress reduction coefficient (r_d), (Seed and Idriss, 1971). Several relationships suggested for calculation of r_d (Youd et al., 2001). The equations of Liao and Whitman (1986), suggested ranges of r_d, that are reasonably consistent with other relationships is used in this study. Hence,

$$r_d = 1.0 - 0.00765z \quad \text{for } z \le 9.15m \tag{5.5}$$

$$r_d = 1.174 - 0.0267z \quad \text{for } 9.15m < z \le 23m \tag{5.6}$$

where z is depth below the ground level.

Liquefaction susceptibility for sands is defined by Cyclic Resistance Ratio (*CRR*). The parameter is calculated by,

$$CRR_{7.5} = \frac{1}{34-(N_1)_{60,CS}} + \frac{(N_1)_{60,CS}}{135} + \frac{50}{\left[10 \cdot (N_1)_{60,CS} + 45\right]^2} - \frac{1}{200} \tag{5.7}$$

where $(N_1)_{60,CS}$ is SPT blow count corrected for equipment dependent variables, fines content and normalization for overburden pressure. The upper limit for $(N_1)_{60,CS}$ is 30. Values of $(N_1)_{60,CS}$ greater than 30 are supposed to depict non-liquefiable deposits (Youd et al., 2002).

Measured SPT blow counts, (N_m) used in analysis were corrected and normalized for overburden pressure by using suggested factors of Youd et al. (2001). Borehole diameter, rod length and sampling method correction factors are given in Table 5.1. For the rod length correction 3 m is added to the depth of borehole in order to estimate the total length of rod.

Overburden pressure correction factor is calculated by (Youd et al., 2001),

$$C_N = 2.2 / (1.2 + \sigma'_{vo} / P_a) \tag{5.8}$$

Table 5.1: SPT blow counts correction factors for borehole diameter, rod length and sampling method (Skempton, 1986; Robertson et al., 1998).

Factor	Equipment Variable	Correction
Borehole diameter	65 – 115 mm	1
	120 mm	1.05
	200 mm	1.15
Rod length	< 3 m	0.75
	3 – 4 m	0.8
	4 – 6 m	0.85
	6 – 10 m	0.95
	10 – 30 m	1
Sampling method	Standard sampler	1
	Sampler without liners	1.1-1.3

The effect of fines content on CRR is not as clear as other factors (Idriss and Boulanger, 2008). The fines content is taken into account by (Youd et al., 2001),

$$(N_1)_{60,CS} = \alpha + \beta \cdot (N_1)_{60,CS} \tag{5.9}$$

where α and β are coefficients dependent on percent of fines, namely the fines content (FC). These are determined by,

$$\alpha = 0 \text{ and } \beta = 1.0 \text{ for } FC \leq 5\% \tag{5.10a}$$

$$\alpha = \exp\left(1.76 - \frac{190}{FC^2}\right) \text{ and } \beta = 0.99 + \frac{FC^{1.5}}{1000} \text{ for } 5 \leq FC \leq 35\% \tag{5.10b}$$

$$\alpha = 5.0 \text{ and } \beta = 1.2 \text{ for } FC \geq 35\% \tag{5.10c}$$

FC is estimated by the sieve analyses of specimens. However, *FC* values were not reported for a number of SPT locations. In these cases, the data from the nearest similar deposits was used. Wherever it is necessary, the data of Kendir (2010) is used as supplementary material.

Cyclic Resistance Ratio ($CRR_{7.5}$), is calculated for a moment magnitude of 7.5. The moment magnitude of 1999 İzmit Earthquake was 7.4 (Erdik, 2001). Therefore, calculated CRR are converted to $CRR_{7.5}$ by the equation,

$$MSF = 10^{2.24} / M_W^{2.56} \tag{5.11}$$

where M_w is moment magnitude of ground motion.

The simplified procedure was suggested for the range of depth less than 15 m (Youd et al., 2001). *FS* should be corrected for high overburden pressures by the factor K_σ according to Hynes and Olsen (1999).

$$K_\sigma = (\sigma'_{vo} / P_a)^{(f-1)} \leq 1.0 \tag{5.12}$$

where σ'_{vo} is effective stress expressed by Equation (5.4), P_a *is* atmospheric pressure (100 kPa) and *f* is density-dependent factor. Density-dependent factor (*f*) is calculated by (Youd et al., 2001),

$$f = \begin{cases} 0.8 & Dr \leq 40\% \\ 0.7 \quad for & 40\% \leq Dr \leq 60\% \\ 0.6 & Dr \geq 80\% \end{cases} \tag{5.13}$$

where D_r is the relative density which is calculated by the empirical relationships for SPT blow counts. A relationship is suggested by Tokimatsu and Seed (1987),

$$D_r = -30.548 \cdot N_i^6 + 92.162 \cdot N_i^5 - 109.34 \cdot N_i^4 + 65.226 \cdot N_i^3 - 21.342 \cdot N_i^2 + 4.6908 \cdot N_i + 0.0039 \tag{5.14}$$

where N_i is equal to $(N_1)_{60}$ / 50. Alternatively, Idriss and Boulanger (2008) suggested,

$$Dr = 100\sqrt{\frac{(N_1)_{60}}{46}} \tag{5.15}$$

The average of Equations (5.14) and (5.15) is used in calculations.

5.3. Estimation of Peak Ground Acceleration

Peak ground acceleration (a_{max}) is estimated using available ground-motion prediction equations (GMPEs) in literature since strong-motion on the site was not recorded during the 1999 İzmit Earthquake. Equations proposed by Chiou and Youngs (2008), and Akkar and Bommer (2010) are used for the estimation of a_{max}. Akkar and Bommer (2010) is developed for Europe, the Mediterranean region and the Middle East including the Turkey region. The reason for the selection of Chiou and Youngs (2008) is that it gives better results for Turkey among a set of widely used GMPEs (Kale and Akkar, 2011). Both GMPEs predict the geometric mean of the two orthogonal horizontal components of ground motion amplitudes. Arithmetic mean of two estimates are used in CRR calculations. Hence, a_{max} is estimated as 0.38g. Other parameters of GMPEs for estimation of a_{max} are presented in Table 5.2.

V_{S30}, the travel-time average of shear-wave velocity (Borcherdt, 1994), is the principal site-condition parameter of the GMPEs. Therefore, the empirical relationship of Hasancebi and Ulusay (2007),

$$V_S = 90 \cdot N^{0.309} \tag{5.16}$$

is used for estimation of V_S, the shear wave velocity, by SPT data. Estimated V_S values are given in Appendix A. The range of V_S is from 110 to 360 m/s for soil layers in the study area. Shear wave velocity in top 30 m of soils, V_{S30}, is estimated by the formula (Borcherdt, 1994),

$$V_{S30} = \frac{30}{\sum_{i=1}^{n} \frac{d_i}{(V_S)_i}} \quad (5.16)$$

where d_i and $(V_S)_i$ are the thickness and shear wave velocity of i^{th} layer and n is the total number of the layers in top 30 m of geological formations. V_{S30} is used to determine two local site parameters of Akkar and Bommer (2010); S_S and S_A. In conclusion, parameter used in Chiou and Youngs (2008) is assumed to be 300 m/s, which is also consistent with the proposed value for soil sites of Turkey provided by Yılmaz et al. (2014). The same value of V_{S30} is also used for determination of S_S and S_A values, 0 and 1, respectively. These values belong to the soil sites (Akkar and Bommer, 2010).

Table 5.2: Parameters used in attenuation relationships provided by Chiou and Youngs (2008), and Akkar and Bommer (2010).

Parameter	Chiou and Youngs (2008) Relationship	Akkar and Bommer (2010) Relationship
M_W	7.4	7.4
$R_X = R_{JB}$	8.5 km	8.5 km
R_{RUP}	8.7 km	Not used
$F_{RV}=F_R$	0	0
$F_{NM}=F_N$	0	0
Z_{TOR}	2 km	Not used
δ	90 °	Not used
V_{s30}	300 m/s	Not used
$F_{Inferred}$	1	Not used
S_S	Not used	0
S_A	Not used	1

The average distance to rupture (R_{JB}) is measured on the map given by Figure 3.6. Dip angle (δ) and moment magnitude is stated in literature (Section 3.4). The depth to top of coseismic rupture (Z_{TOR}) is assumed as 2 km. These geometric properties of fault rupture and the distance to site are shown in Figure 5.2.

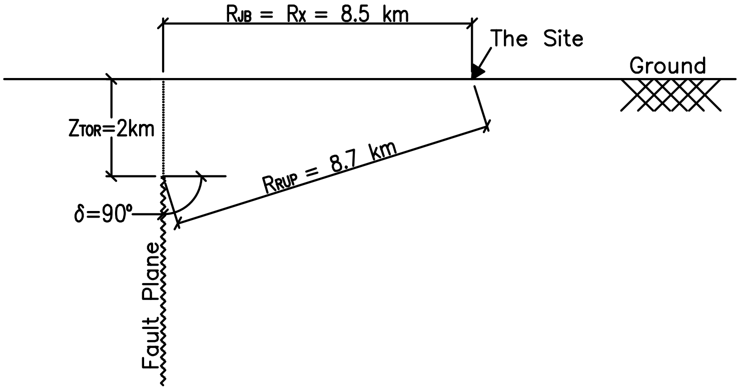

Figure 5.2: Distance parameters used in GMPEs.

The median estimation for a_{max} is 0.41 g according to the relationship of Chiou and Youngs (2008) and 0.35 g according to the relationship of Akkar and Bommer (2010). Hence, the arithmetic average of these estimations, 0.38 g, is used in Equation 5.2.

5.4. Liquefaction Potential of Sample Boreholes

FS against liquefaction (Equation 5.1) is calculated for each SPT result in saturated sandy soils. Boreholes presented by CMSP report and identified by an "*A*" prefix (Appendix A) involve deposits having liquefaction potential, except for *A5*, *A6*, *A8*, *A9*, *A12*, *A16*, *A17*, *A19* and *A20*. The boreholes presented by Kendir (2010) are identified by "*F*" prefix (Appendix A). Boreholes identified as *F1*, *F3, F4, F5, F6 and F7* involve layers with liquefaction potential (*FS<1*).

Calculations are presented in Appendix C. Thickness of layers having liquefaction potential are shown in Figure 5.3. The center of each mark shows the location of pertinent borehole. The statistics for collapsed buildings are compared with the data for liquefaction potential in Figure 5.4. The statistics for both standing and collapsed buildings are shown in Figure 5.5.

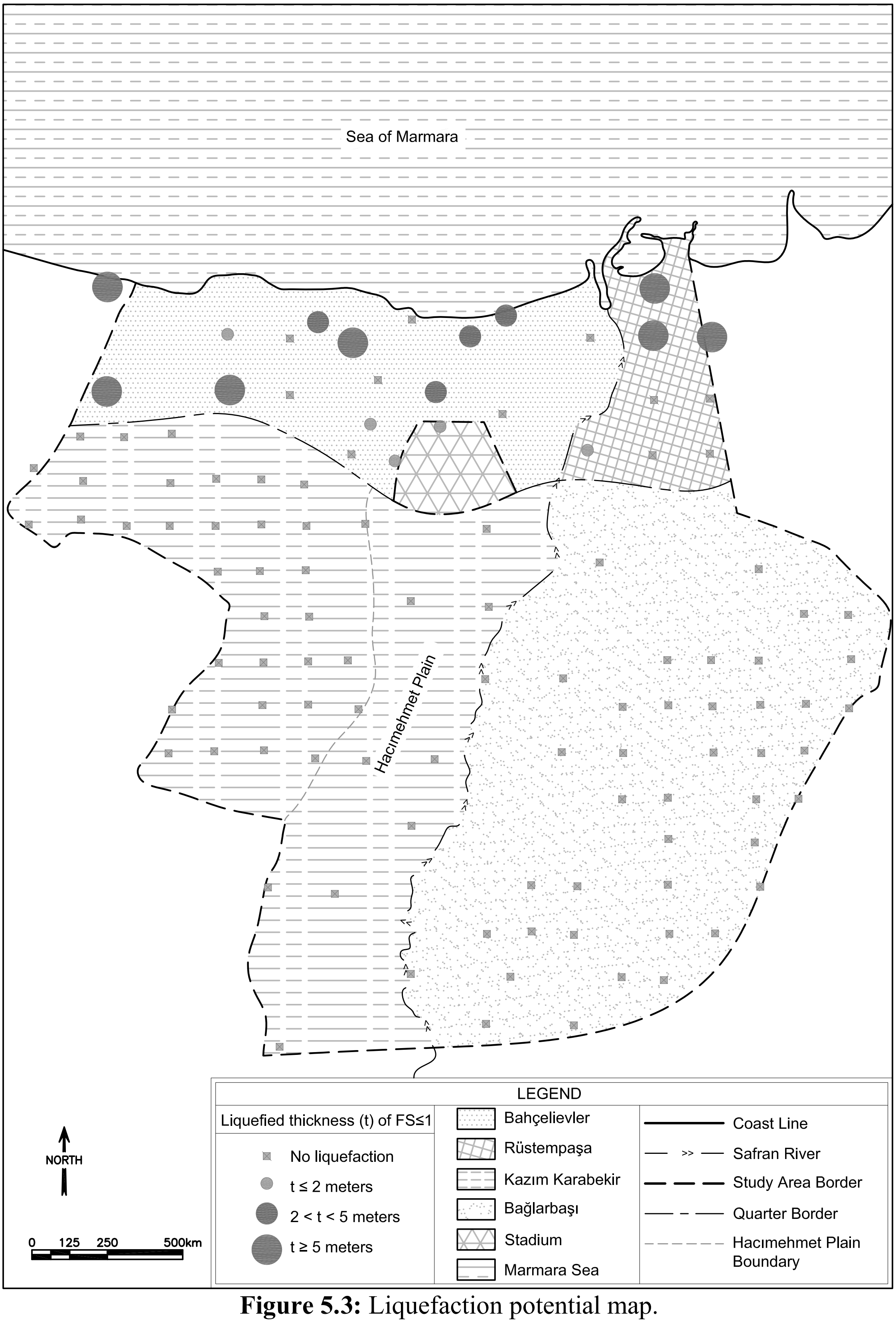

Figure 5.3: Liquefaction potential map.

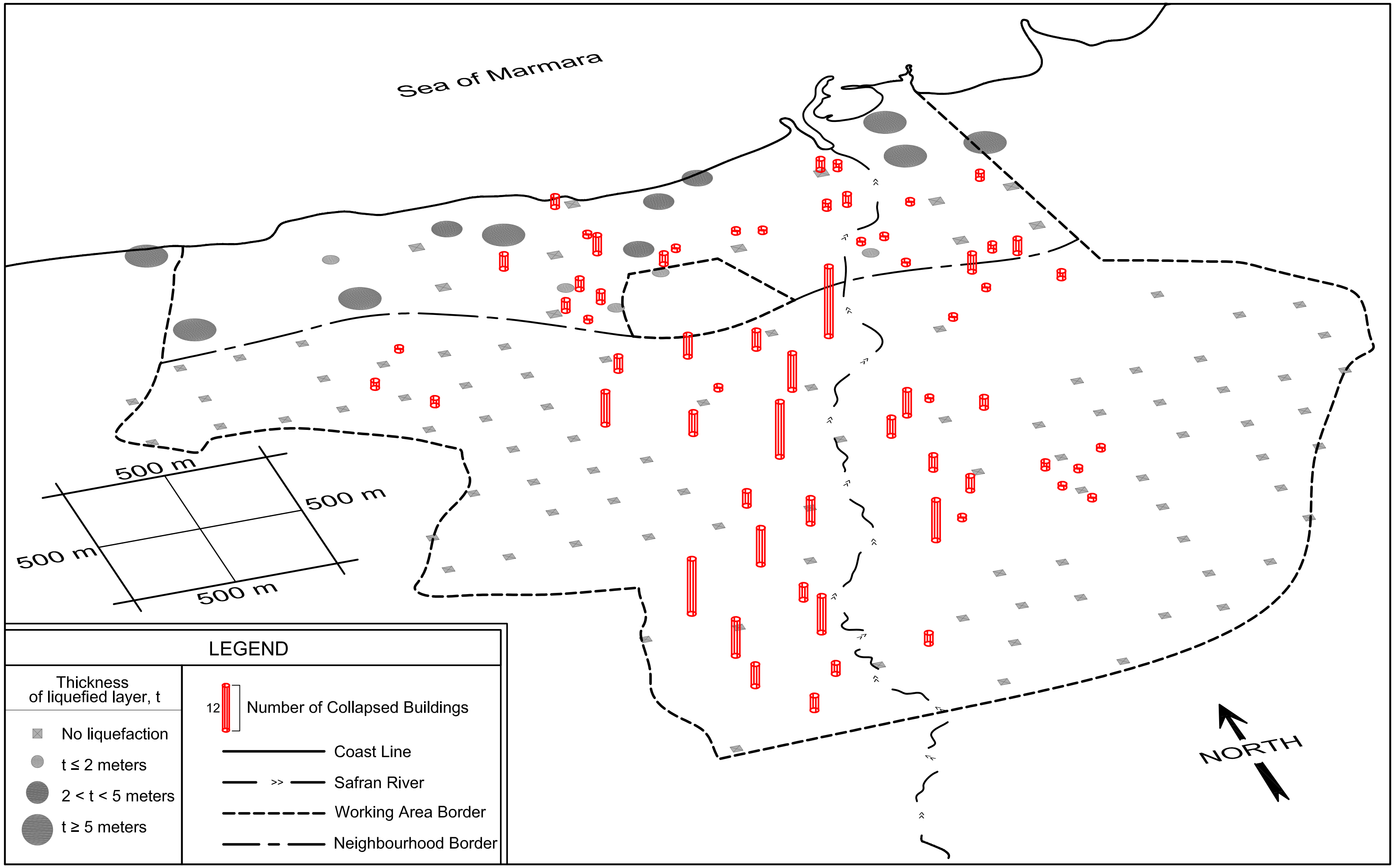

Figure 5.4: A comparison for the spatial distribution of collapsed buildings and thickness (t) of layers having liquefaction potential.

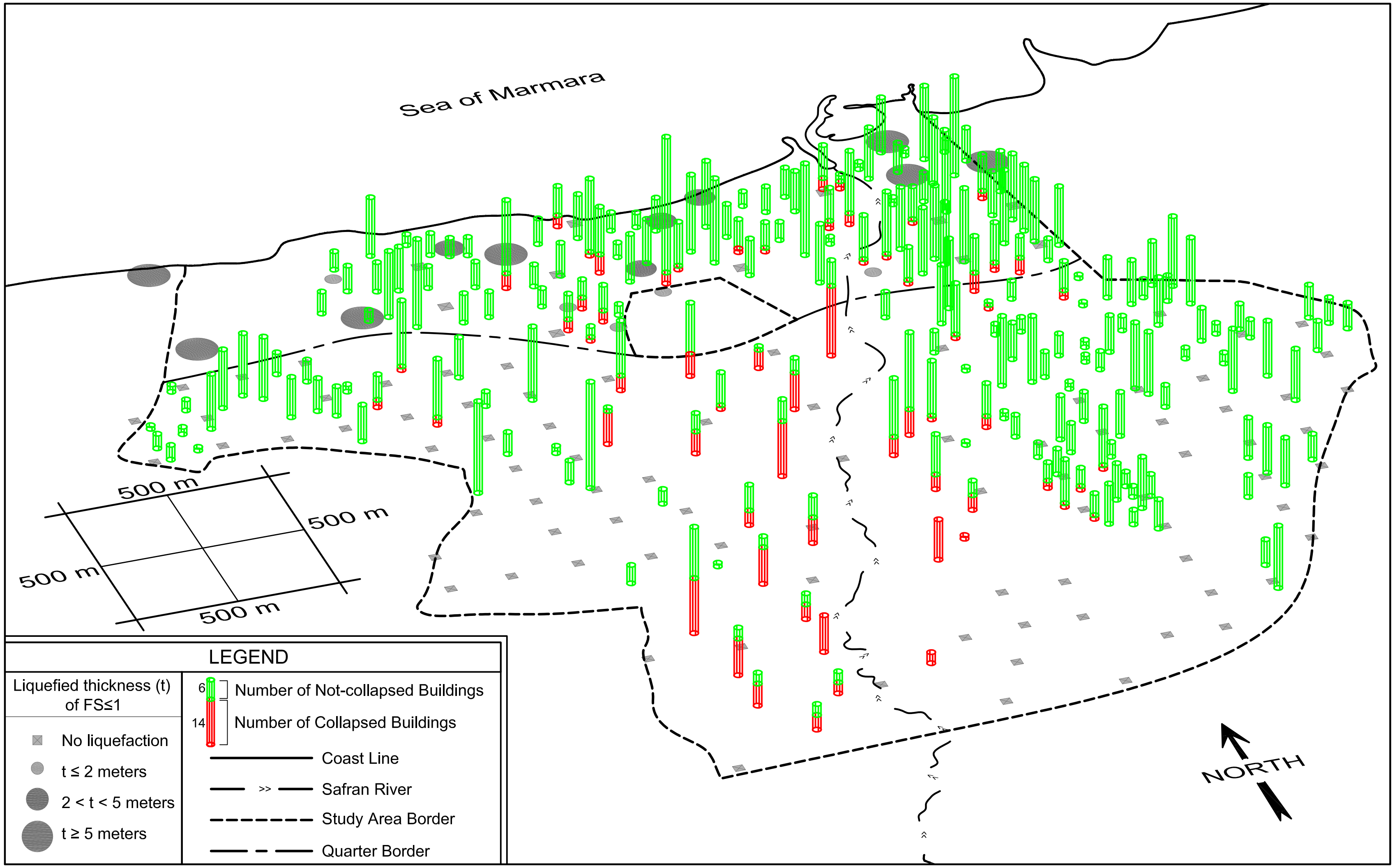

Figure 5.5: A comparison for the spatial distribution of standing-collapsed buildings and thickness (*t*) of layers having liquefaction potential.

CHAPTER 6

SITE RESPONSE ANALYSES AND RESULTS

6.1. Introduction

Variation of building damage intensity caused by the 1999 Izmit Earthquake in the City Centre of Yalova is significant from district to district within the study area as described in Chapter 4. In order to demonstrate that local site effects might have been influential during the earthquake, a series of site response analyses are conducted. In this chapter, the methodology of site response analyses, which covers ground motion selection and scaling, attenuation relations and calculations used to predict target acceleration response spectra, are outlined.

Cyclic1D software used for the site response analyses, is also briefly introduced. Results of site response analyses for the idealized profiles representing the main characteristics of the districts with three different soil profiles are presented.

6.2. Cyclic1D

Cyclic1D-version beta 2.1.5 used for site response analyses in this study is available at "*http://soilquake.net/cyclic1d*". The software operates in Windows operating system with a user interface. The software is introduced by users' manual of the software Elgamal (2015), as follows:

"Cyclic1D is a nonlinear Finite Element program for one-dimensional (1D) lateral dynamic site response simulations. The program operates in the time domain, allowing for linear (Hughes (1987)) and nonlinear studies. Nonlinearity is simulated by incremental plasticity models to allow for modelling permanent deformation and for generation of hysteretic damping. For analysis of dry as well as saturated strata, the finite elements are defined within a coupled solid-fluid (u-p) formulation (Chan (1988), Ziekiewicz et al. (1990)). Dry and/or saturated soil profiles may be studied. In saturated cohesionless soil strata, liquefaction and its effects on ground acceleration and permanent deformation are modelled."

Non-linear material behaviour is implemented in the software with soil back-bone curves controlled by the number of yield surfaces, as illustrated in Figure 6.1.

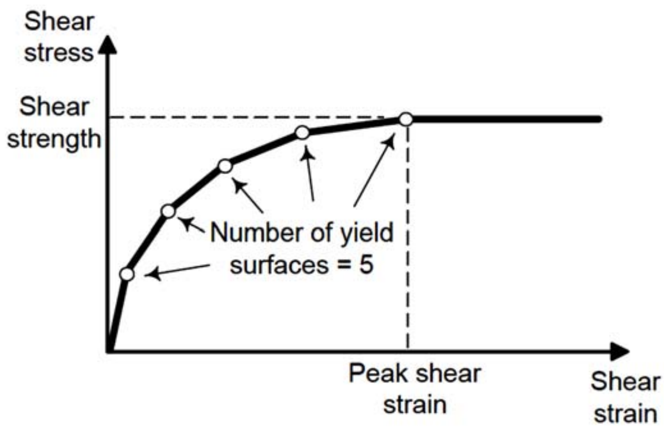

Figure 6.1: Soil backbone curve and yield surfaces used in *Cyclic1D* (Elgamal, 2015).

According to Elgamal (2015), "*the liquefaction model Figure 6.2 employed in Cyclic1D is developed within the framework of multi-yield-surface plasticity. In this model, emphasis is placed on controlling the magnitude of cycle-by-cycle permanent shear strain accumulation in clean medium to dense sands.*"

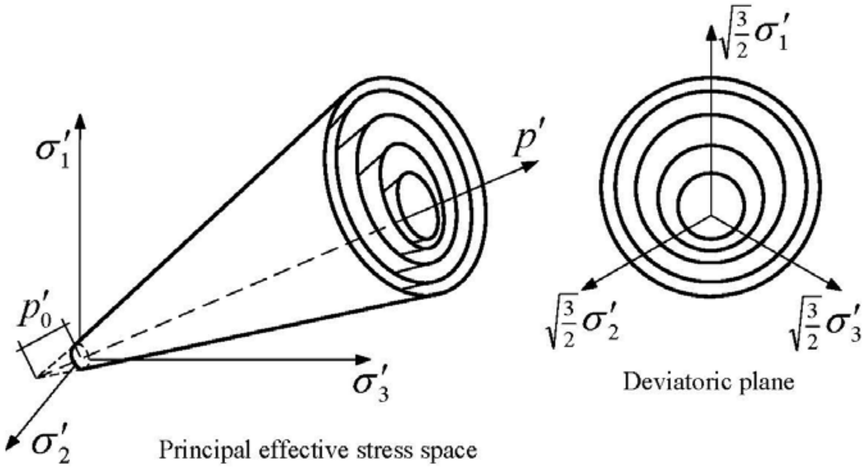

Figure 6.2: Multi-yield surfaces in principal stress space and deviatoric plane (Elgamal, 2015).

In addition, viscous damping (Rayleigh damping) is used by the software and it is controlled by input of damping values – or damping constants – corresponding to reference frequencies.

6.3. Idealized Soil Profiles

Site response analyses are performed with three idealized soil profiles representing the three different sites of the study area shown in Figure 6.3. These soil profiles, named *Profile A*, *B* and *C,* represent the three different site conditions of the study area as described in Section 3. The soil parameters of idealized profiles are estimated or assumed per in-situ investigations outlined in this chapter.

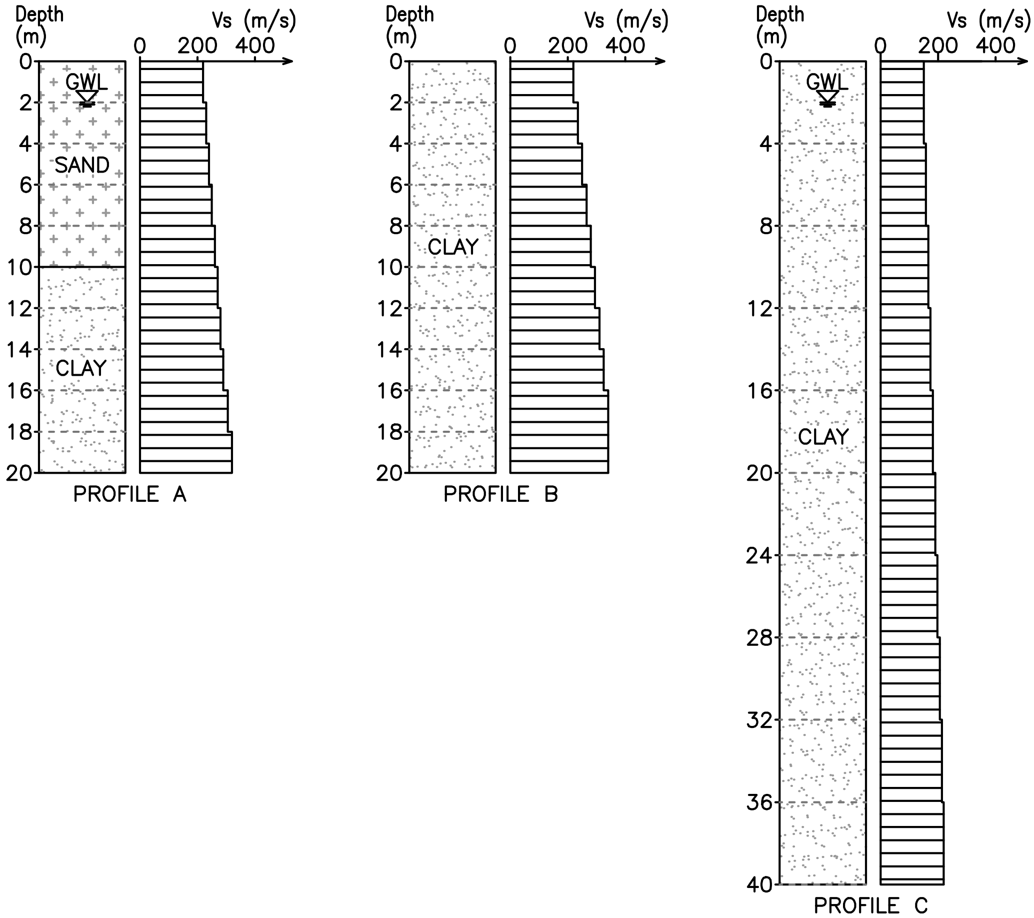

Figure 6.3: Idealized soil profiles used in site response analyses.

Profile A represents the idealized form of liquefiable soil deposits at Bahçelievler and Rüstempaşa Quarters. It consists of a 20 m thick soil profile with 10 m liquefiable layer overlying a 10 meters stiff clay layer. In addition, ground water level at 2 m depth is assumed on the basis of in-situ test data.

Profile B is used to characterize the relatively stiff clay soils at the ridges of the study area, namely west of Kazım Karabekir and east of Bağlarbaşı Quarter, where corresponding boreholes given with a prefix "*B*" and "*D*", respectively. No ground water assigned to this profile, based on the borehole data.

Profile C represents the relatively soft and deep clay deposits at the Hacımehmet Basin and west of Bağlarbaşı Quarter. Depth of the idealized profile is determined as 40 m with 2 m deep ground water level according to borehole data given with a prefix "*C*".

As previously stated, V_s values are estimated using an available correlation in literature given in Equation (5.18). Calculated values of V_s are presented in Appendix A. As a result of these calculations, it can be said that V_s values of soils in the study appear to be within a range between 110 and 360 m/s. The majority of the V_s values are between 150 and 340 m/s. Shear wave velocities of idealized soil *Profiles A*, *B* and *C* are determined in this range and shown in Figure 6.3. Furthermore, a gradual increase in *Vs* values by depth is provided for idealized soil profiles in order to eliminate possible marginal refraction and reflection of wave propagation.

Undrained shear strength of clayey soils (c_u), one of the major input parameters of non-linear response analysis, is estimated using correlation with *SPT* blow counts by (Kulhawy and Mayne, 1990),

$$\frac{c_u}{P_a} = 0.06 \cdot N_{60} \tag{6.1}$$

where P_a is atmospheric pressure and N_{60} is *SPT* blow count corrected for 60% equipment efficiency. Estimated range of c_u are also presented in tabular form in Appendix A. Cohesion of sand materials are ignored in the analyses and values of angle of friction are estimated by (Peck et al., 1974),

$$\phi' = 27.1 + 0.3 \cdot N_{60} - 0.00054 \cdot N_{60}^2 \tag{6.2}$$

where N_{60} is *SPT* blow count corrected for 60% equipment efficiency. Estimated results of ϕ' are also presented in tabular form in Appendix A.

As previously mentioned in Section 3, alluvial deposits lay on a sedimentary formation named Kılıç Formation which continues up to approximately 700 m depth in the region. Therefore, bedrock – elastic half space – having a shear-wave velocity of 530 m/s is assumed according to Yılmaz et al. (2014) as given for the sedimentary formations. Also, default damping values that have 2% at 1 Hz and 6 Hz frequencies are assigned to each analysis model. Number of yield surfaces is selected as 20, which is considered sufficient to represent the non-linearity of soil, with a 5% peak strain value. Rest of the input parameters that are assumed with respect to the recommended range indicated in users' manual of the software. Used parameters and the respective recommended ranges are given in Table 6.1.

Confinement dependence coefficient (n) is used to model the increase in V_S by depth, and it is applicable for sand layers (Elgamal et al., 2015).

$$V_S = V_{Sr} \cdot (p / p_r)^{n/2} \tag{3.3}$$

where V_{Sr} denotes the reference shear wave velocity of soil layer, p_r denotes reference mean confinement for determined reference shear wave velocity, and p denotes mean confinement at any depth.

Parameters utilized for pore-pressure effects (liquefiable sand parameters) (Elgamal et al., 2015):

Dilation parameter 1 (d_1), and *dilation parameter 2* (d_2) respectively dictates the rate of volume expansion (or the dilation rate), and the effect of accumulated shear strain on this rate by the exponential factor $d_1 \cdot \exp(d_2 \cdot \gamma_d)$.

Contraction parameter 1 (c_1)*, and contraction parameter 2* (c_2) respectively dictates the rate of pore pressure build-up under undrained conditions, and the effect of overburden pressure on contraction behaviour by the factor $c_1 \cdot (p/p_d)^{C2}$.

Liquefaction parameter 1 dictates the extent of limits of shear strain accumulation during each shearing cycle.

The remaining parameters shown in Table 6.1 are conventional parameters of geotechnical engineering related to shear strength, permeability and density of soils.

Table 6.1: Soil properties of the idealized profiles used as input in site response analyses. Together with the default values of cohesive and non-cohesive soils and recommended ranges of each parameter provided on users' manual of *Cyclic1D* software (Elgamal et al. 2015).

Parameters	Profile A Sand	Profile A Clay	Profile B Clay	Profile C Clay	Default Medium Sand	Default Medium Clay	Recommended Range
Mass Density (kN/m³)	19	19	19	19	19	15	10 - 30
Reference shear wave velocity (m/s)	220-260	270-320	220-340	150-220	203.3	200	10 - 6000
Shear strength (kPa)	-	200	200	80	-	-	10 - 5.0+E5
Reference effective mean confinement (kPa)	100	-	-	-	80	50	>10
Confinement dependence coefficient	0.5	-	-	-	0.5	-	0.1 - 1
Initial lateral/vertical confinement ratio	0.67	0.5	0.5	0.5	0.67	0.67	0.1 - 0.9
Angle of friction (degree)	32	-	-	-	31.4	-	5 - 65
Peak shear strain (%)	5	5	5	5	5	5	0.001 - 20
Number of yield surfaces	20	20	20	20	20	20	0 - 30
Dilation angle (degree)*	26	-	-	-	26.5	-	5 - 65
Contraction parameter 1*	0.2	-	-	-	0.19	-	0 - 0.3
Contraction parameter 2*	0.2	-	-	-	0.2	-	0.2 - 0.6
Dilation parameter 1*	0.2	-	-	-	0.2	-	0 - 0.6
Dilation parameter 2*	10	-	-	-	10	-	10
Liquefaction parameter 1*	0.015	-	-	-	0.015	-	0 - 0.025
Permeability coefficient (m/s)	6.6E-05	-	-	-	6.6E-05	1.0E-09	-

*Liquefiable sand parameters.

6.4. Target Acceleration Response Spectra

No ground motion was recorded in City Centre of Yalova during 1999 Izmit Earthquake. In order to estimate the acceleration response spectra at the site due to the earthquake, available attenuation relations in literature are used to predict the seismic demand. Similar input parameters utilized earlier for the estimation of peak ground acceleration estimation in Section 5.3, except for V_{S30} parameter are also used for the estimation of response spectra. In this case, it is determined that V_S of estimated material is 530 m/s, as specified for mean of sedimentary rock formations by Yılmaz et al. (2014). Input parameters used in two approaches are given in Table 6.2. Arithmetic mean of two estimated acceleration spectra is used in determining the target spectrum and it is given in Figure 6.4. After the determination of target response, selected ground motions are scaled as introduced in the following section.

Table 6.2: Parameters used in attenuation relationships provided by Chiou and Youngs (2008), and Akkar and Bommer (2010).

Parameter	Chiou and Youngs (2008)	Akkar and Bommer (2010)
M_w	7.4	7.4
$R_x = R_{JB}$	8.5 km	8.5 km
R_{RUP}	8.7 km	Not used
$F_{RV}=F_R$	0	0
$F_{NM}=F_N$	0	0
Z_{TOR}	2 km	Not used
δ	90 °	Not used
V_{s30}	3 m/s	Not used
$F_{Inferred}$	1	Not used
$Z_{1,0}$	90.6 m	Not used
S_S	Not used	0
S_A	Not used	1

6.5. Ground Motion Selection and Scaling

Methodology proposed by Kalkan and Chopra (2010) is used for the selection of earthquake records used in site response analyses. Following parameters are underlined in this study for earthquake record selection from the database of PEER (2014): fault rupture characteristic, magnitude of earthquake, distance to rupture and local soil properties.

Strike-slip type events with a magnitude higher than 6.5 are searched in the database, and, five ground motion records are selected including 1999 Izmit Earthquake ground motion recorded in Düzce by using distance to rupture of the working site (~8.5 km) and local site characteristic – shear wave velocity – similar to the working site. Selected earthquakes and their related parameters are given in Table 6.3. Selected records are obtained from the database as processed (baseline corrected and filtered for high frequency content).

Table 6.3: Selected earthquake records from the database of PEER (2014).

Event	Year	Station	Record ID	Scale Factor	M_w	Fault Type	R_{rup} (km)	V_{s30} (m/s)
İzmit, Turkey	1999	Düzce	1158	0.925	7.51	strike slip	15	282
Düzce, Turkey	1999	IRIGM 498	8166	1.046	7.14	strike slip	4	425
Landers, US	1992	Coolwater	848	0.870	7.28	strike slip	20	353
Darfield, New Zealand	2010	DFHS	6893	0.824	7.00	strike slip	12	344
Kobe, Japan	1995	Kakogawa	1107	1.141	6.90	strike slip	23	312

Prior to use of selected ground motions as input, geometric mean of the two horizontal acceleration response spectra are scaled with respect to the target acceleration spectra in accordance with ASCE 7-05 provisions. The range of recommended spectral scaling is $0.2T$ to $1.5T$ where T is the fundamental period of the structure.

Mean story number representative of the buildings is determined as approximately 4 stories. The fundamental period of a 4 story reinforced concrete building is estimated as 0.4 s by (NEHRP, 1994),

$$T = 0.1 \cdot N_s \tag{6.4}$$

where N_s is the number of stories.

Accordingly, the range of spectral scaling is determined as 0.1 to 0.6 s. As an additional consideration, upper boundary is extended up to 1.0 s to take non-linearity into account. As a result, 0.1 to 1 s range of target spectra used for spectral scaling of the selected records. Acceleration, velocity and displacement versus time histories of selected records' components scaled by the factors stated in Table 6, are given in Appendix D.

Acceleration response spectra of scaled selected motions with 5% elastic damping are shown in Figure 6.4 with respect to geometric mean of two orthogonal components of each ground motion. Local site effects are investigated by use of selected ground motion records as input motion.

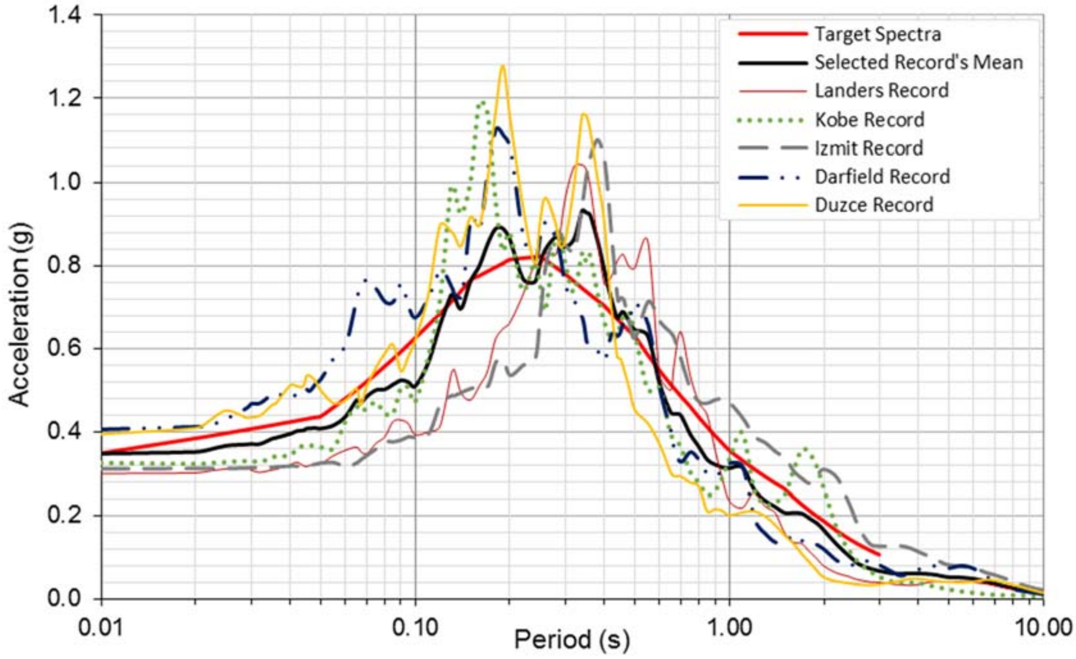

Figure 6.4: Target acceleration response spectra, acceleration response spectra of scaled ground motions and arithmetic mean of acceleration response spectra of selected ground motions (with 5% damping).

6.6. Results of Site Response Analyses

Site response analyses of the idealized *Profiles A*, *B* and *C* are conducted with the previously stated parameters. Results of the analyses are presented in the form of acceleration spectra and spectral acceleration amplification factors for each earthquake record. They are given under this section with respect to the geometric mean of acceleration response spectra of the two orthogonal horizontal components. Amplification factors are calculated by dividing the acceleration response spectra by 5% damped response spectra of each motion. Resultant spectral acceleration amplification graph is presented using geometric mean of horizontal acceleration spectra of the earthquake motions. Individual acceleration response spectra and spectral amplification factors of the each earthquake record components are presented in Appendix E.

Time history of pore pressure ratio *(r_u)* for liquefiable soil layer at 7 m depth of *Profile A*, is obtained as in Figure 6.5. Ratio of excess pore pressure overall tends to increase with time due to contractive behaviour of sand. Instant reductions of pore pressure observed in the plot occur due to momentary dilative response of the sand during seismic shaking. Increase of r_u to 1 is an indication of drastic reduction in soil strength.

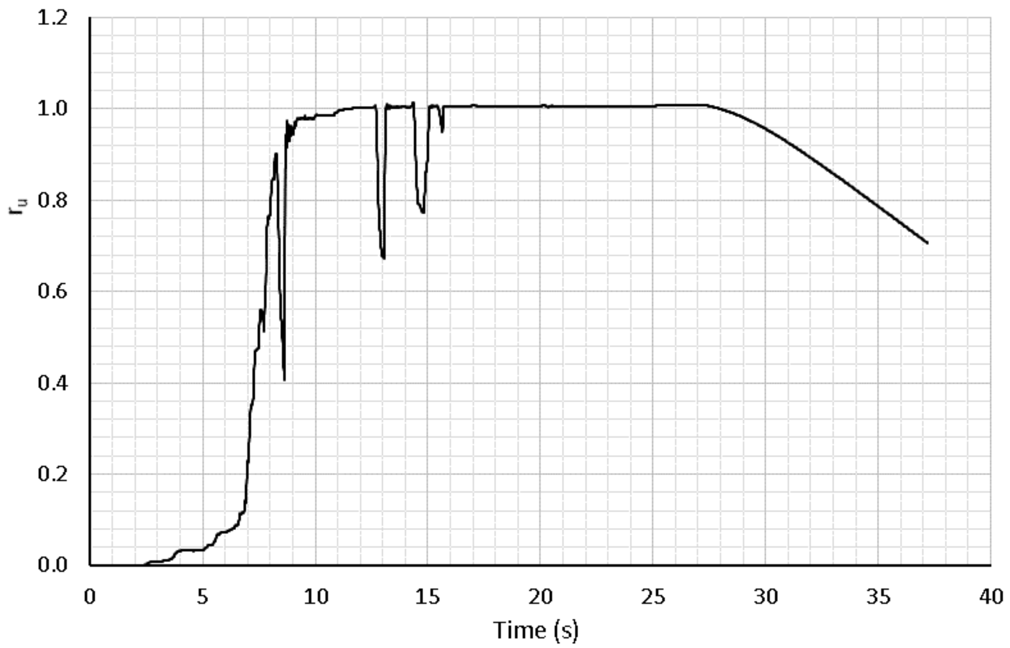

Figure 6.5: Pore pressure ratio time history of *Profile A* at 7 m depth for İzmit record NS component.

Stress versus strain hysteresis for *Profile A* at 7.5 m depth is given in Figure 6.6. It covers time history from beginning of excitation up to a few cycles following triggering of liquefaction. Afterwards, the hysteresis exhibits a chaotic behaviour where large strains take place with shear strength values close to zero.

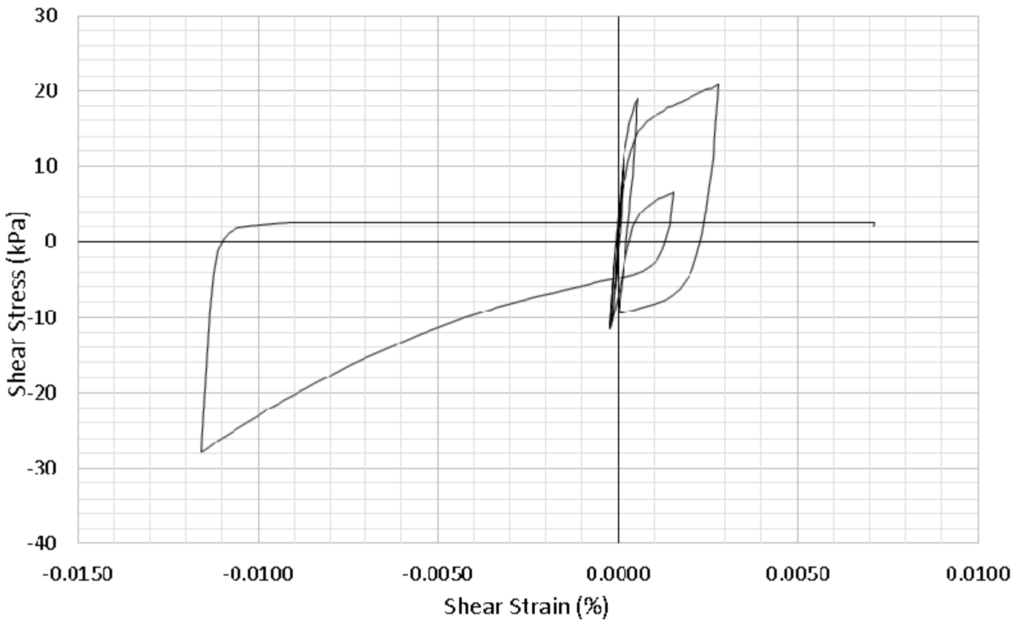

Figure 6.6: Stress versus strain plot of *Profile A* at 7 m depth for İzmit record NS component.

Stress-strain diagrams of *Profile A* are also presented in Appendix E in Figures E.11 through E.16 for north-south component of İzmit record for the depths between 0.5 and 9.5 m. According to these plots, strains decrease by decreasing depth in the profile and limited strains take place near the ground surface.

Results for İzmit Record

Acceleration response spectra and spectral acceleration amplification factors belonging to each profile are presented with Figures 6.7 and 6.8, respectively. In these figures, geometric mean of the two horizontal components of İzmit record are considered. They indicate that maximum spectral acceleration occurs at about 0.3-0.4 s period for each profile. Higher amplification takes place for *Profile B* and for liquefaction-disabled case of *Profile A* with approximately similar amplification ratios between 0.1 and 1.0 s. Liquefiable case of *Profile A* and *Profile C* exhibit de-amplification behaviour for this period range. Acceleration response spectra of amplification graphs of each component are presented in Appendix E.

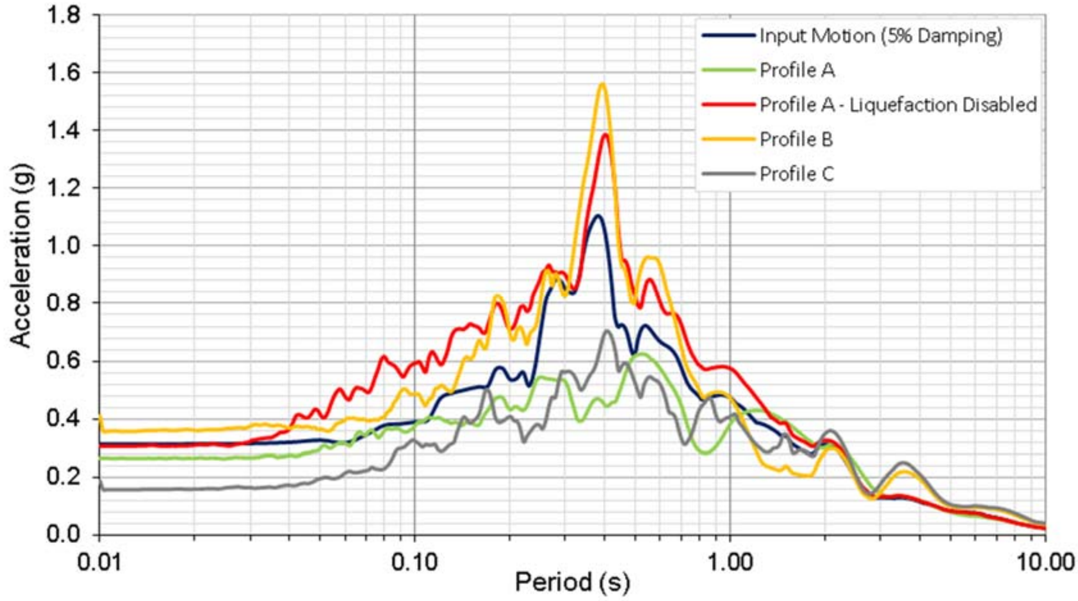

Figure 6.7: İzmit record - geometric mean of acceleration response spectra of two horizontal components.

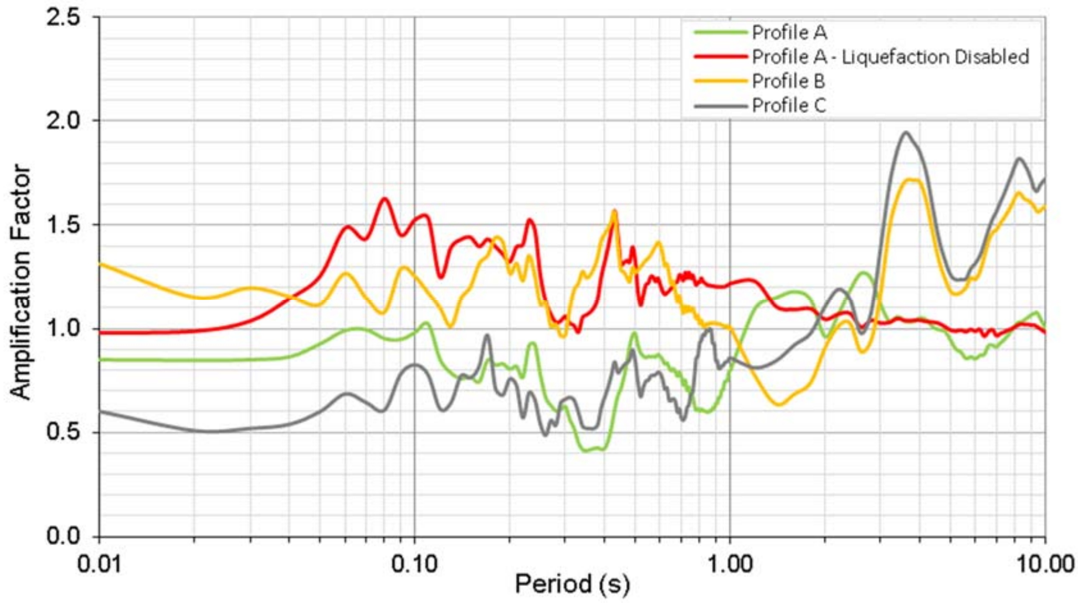

Figure 6.8: Amplification of spectral accelerations of İzmit record.

Shear wave velocity – *SPT* blow count correlations depend on a limited set of data and soil type, and their standard deviation determined by *SPT* correlations can be quiet high accordingly. Considering the probability of underestimating shear wave velocities of residual formations, additional site response analyses are conducted with *Profiles A', B'* and *C',* which are similar to *Profiles A*, *B* and *C*, respectively, except for the 50% increased V_s values. These profiles are analysed for NS component of İzmit record. Acceleration response spectra and spectral acceleration amplification factors are presented in Figures 6.9 and 6.10, respectively.

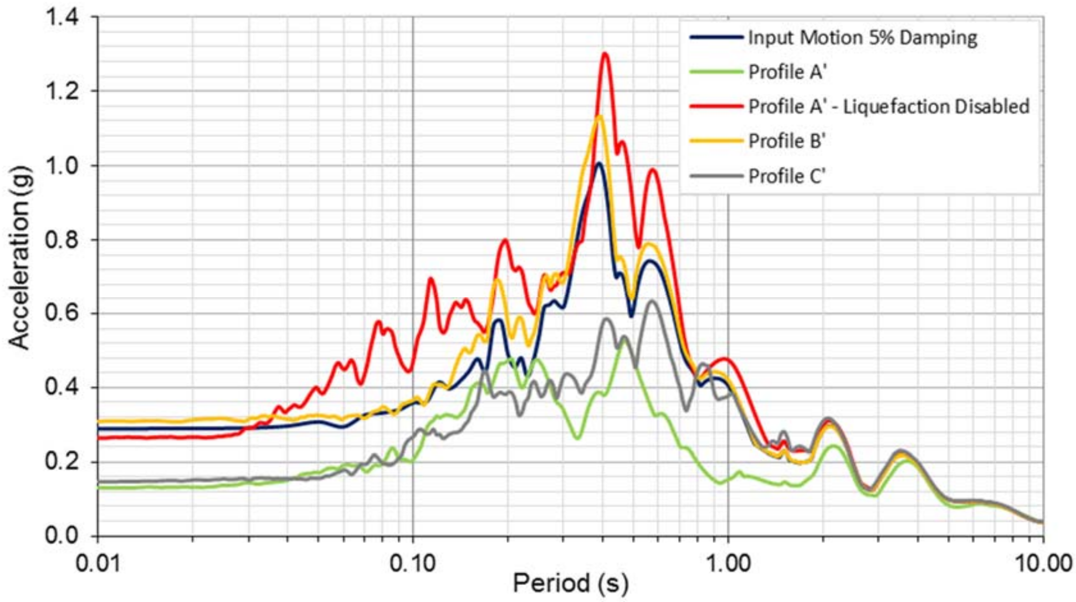

Figure 6.9: Response spectra of İzmit record NS component for the idealized *Profiles A'*, *B',* and *C'*, where shear wave velocities of soil layers are increased 50%.

As can be observed from the figures, no significant change in amplification results were observed from these additional analyses with increased shear wave velocities. Only, a minor increase at spectral accelerations is obtained for *Profile A'* and *Profile C'*.

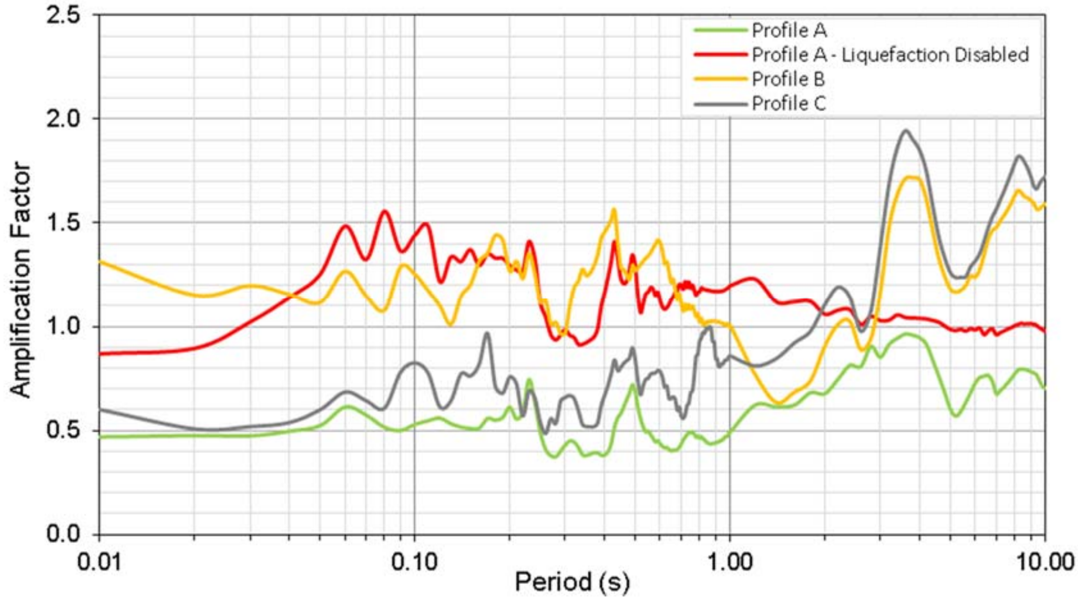

Figure 6.10: Amplifications of response spectra of NS component of İzmit record for the *Profiles A*', *B',* and *C'*, where shear wave velocities increased 50%.

Results for Düzce Record

Acceleration response spectra belonging to each profile, and spectral acceleration amplification factors for Düzce record are given in Figure 6.11 and 6.12, respectively. They are based on the geometric mean of the two horizontal components of the record. They indicate that maximum spectral acceleration occurs at about 0.3-0.4 s period for each profile, which is similar to the results obtained from İzmit record. However, peaks are also observed near 0.2 s period for this record. Amplification values for *Profile B* and liquefaction-disabled case of *Profile A* are similar between 0.1 and 1 s periods. Liquefiable case of *Profile A* and *Profile C* exhibit de-amplification for this period range. Also, an amplification factor of 0.25 is observed at the liquefied profile. After 1 s period, significant reduction takes place in all of the analysed profiles.

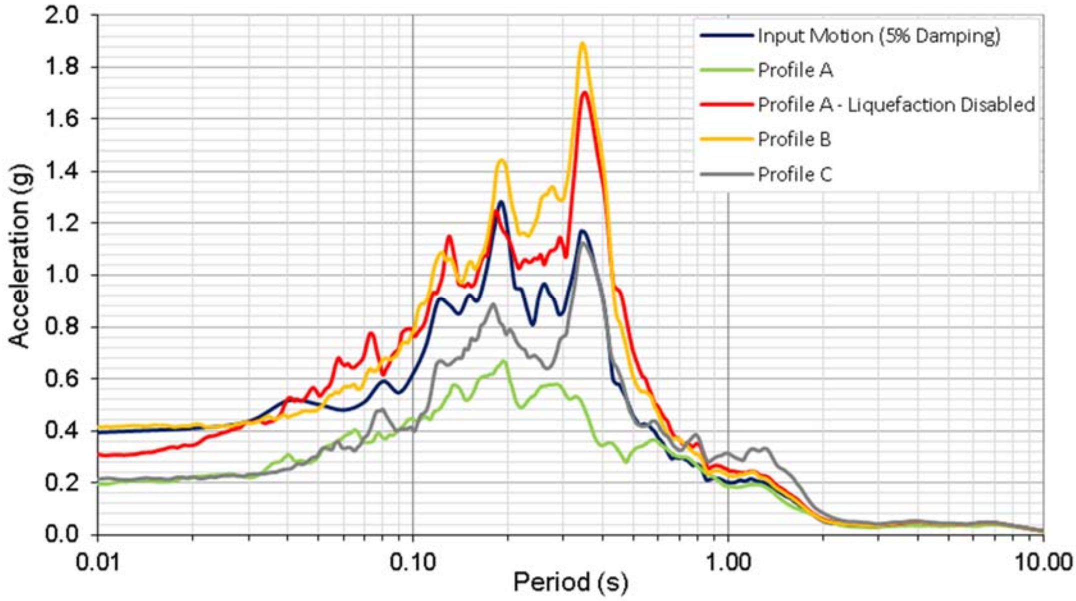

Figure 6.11: Düzce record - geometric mean of acceleration response spectra of two horizontal components.

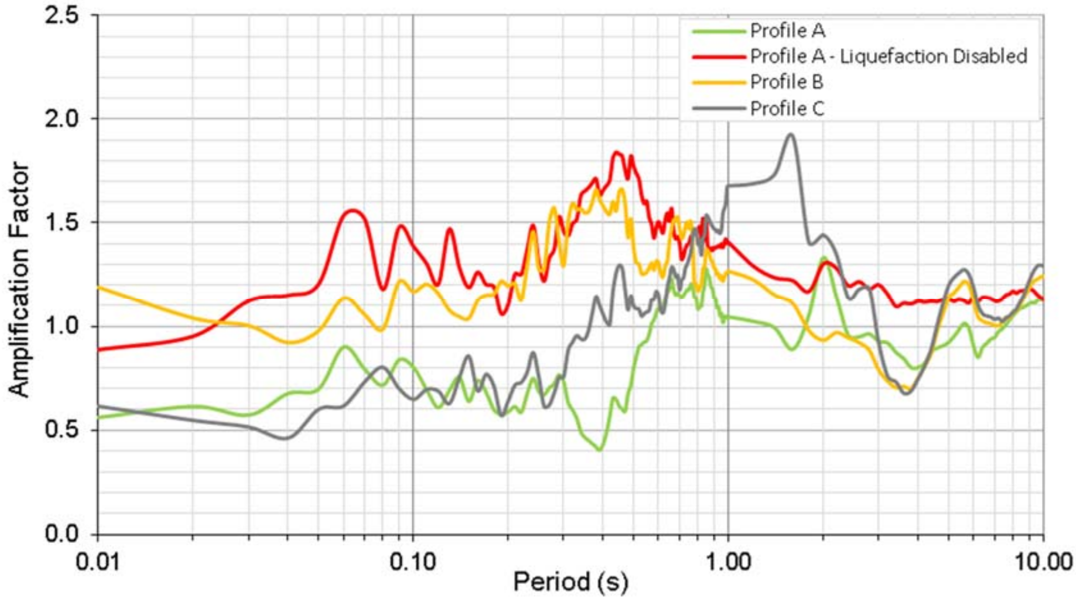

Figure 6.12: Spectral amplifications for Düzce record.

Results for Landers Record

Acceleration response spectra for idealized profiles for Landers record excitation are presented with Figure 6.13 and the respective plot of spectral acceleration amplification ratio is given in Figure 6.14. Response spectra and amplification plots of each the components are presented in Appendix E. There is almost no amplification for the 0.1 to 1 s interval for *Profile C*. Besides, *Profile B* and liquefaction-disabled case of *Profile A* exhibit a similar amplification of about 1.5 times. However, *Profile C* de-amplifies for the same period and de-amplification ratio decreases down to about 0.2 times of input at 0.7 s.

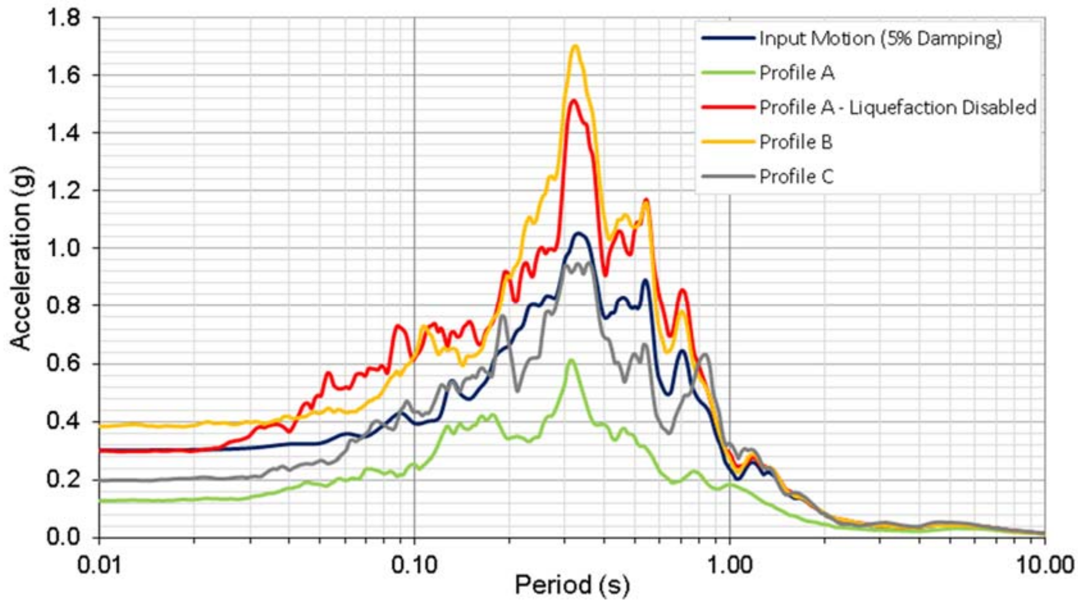

Figure 6.13: Landers record - geometric mean of acceleration response spectra of two horizontal components.

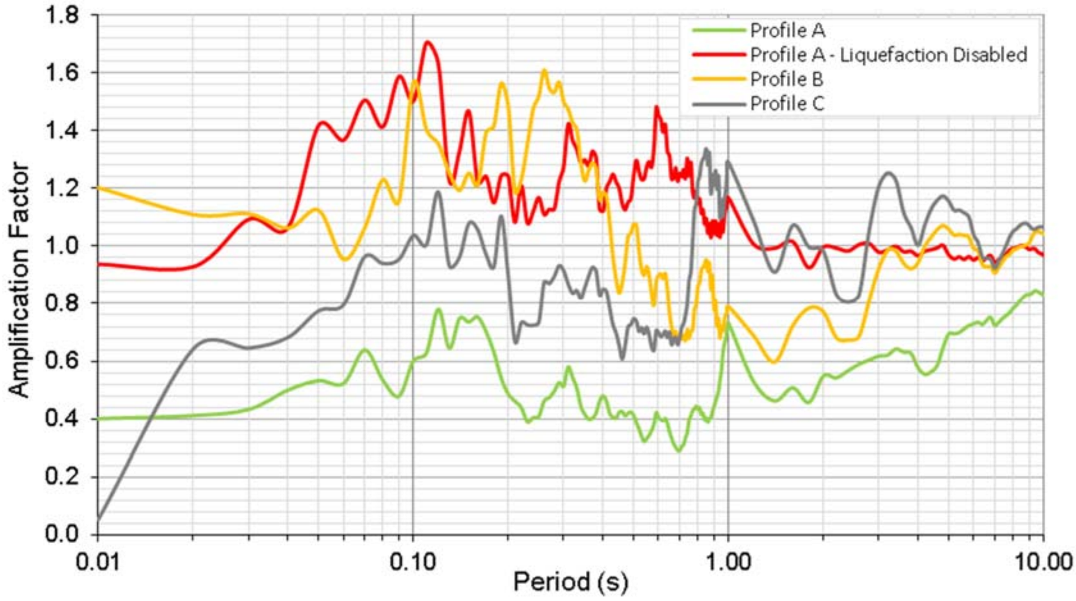

Figure 6.14: Spectral amplifications for Landers record.

Results for Darfield Record

The results for the geometric mean of the two horizontal components of Darfield record are presented with Figures 6.15 and 6.16. The rest of component based results are presented in Appendix E. Amplification for Darfield record is limited for *Profile B* and for the liquefaction disabled case of *Profile A* for 0.1 to 1 s period. The liquefaction-enabled case of *Profile A* exhibits de-amplification ratios between 0.2 and 0.4 for the same interval. The spectral amplification between 0.1 s and 0.3 s for is small for *Profile C*.

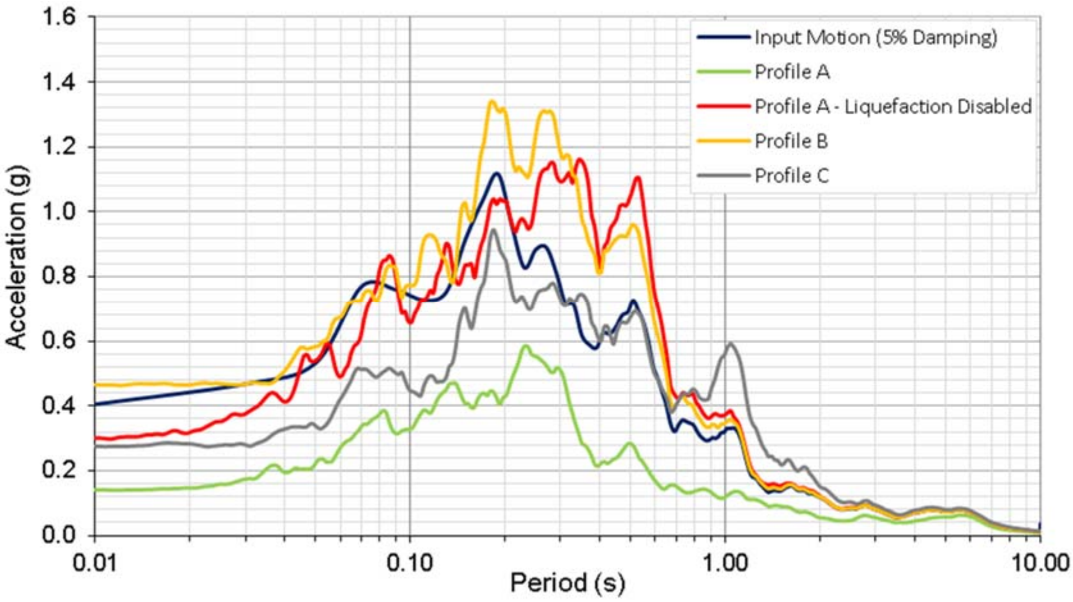

Figure 6.15: Darfield record - geometric mean of acceleration response spectra of two horizontal components.

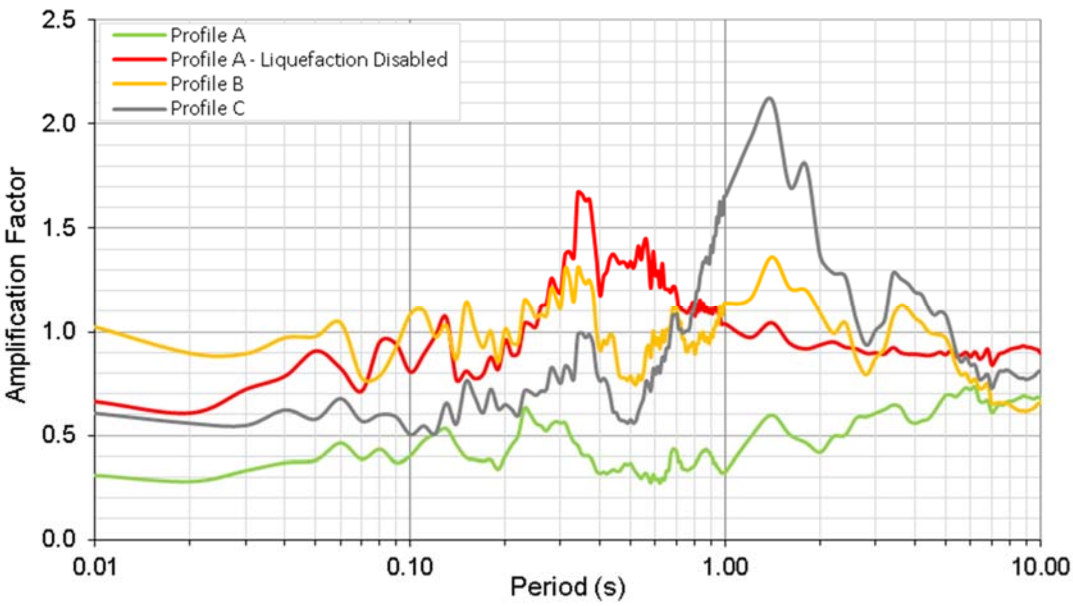

Figure 6.16: Spectral amplifications for Darfield record.

Results for Kobe Record

The results of the geometric mean of two horizontal components of Kobe record are presented in Figures 6.17 and 6.18. Result for each of the individual components are provided in Appendix E. While the non-liquefied case of *Profile A* amplifies with a ratio increasing up to 2, liquefied case of the same profile de-amplifies up to a ratio of 0.5 between 0.1 to 1.0 s intervals. On the other hand, there is a limited amplification for *Profile B*. Response spectra belonging to *Profile C* is also not amplified, in fact it is even de-amplified with an average ratio of 0.7 for Kobe record.

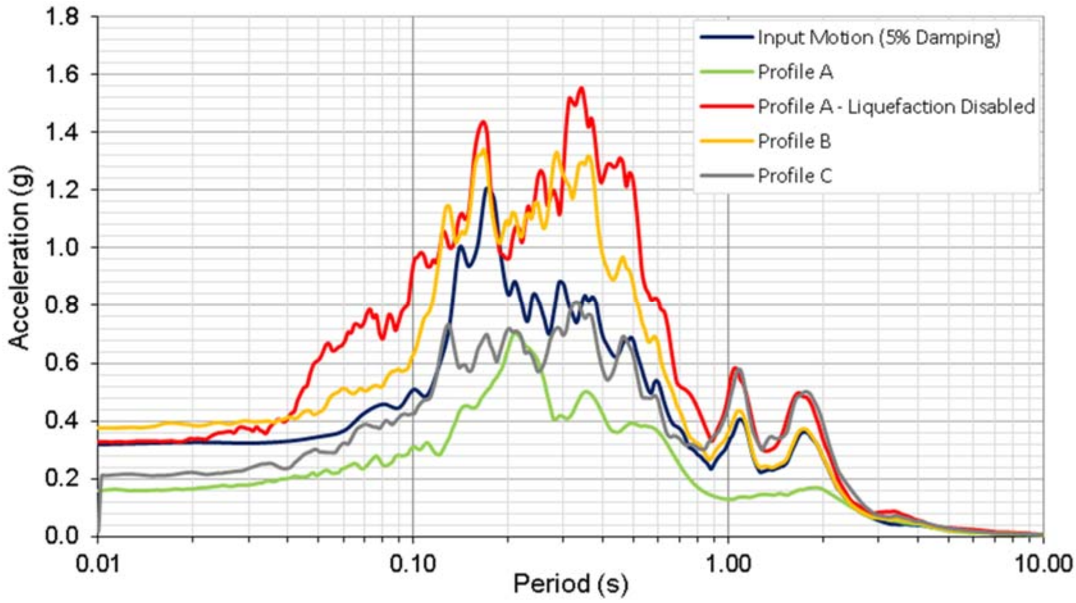

Figure 6.17: Kobe record - geometric mean of acceleration response spectra of two orthogonal horizontal components.

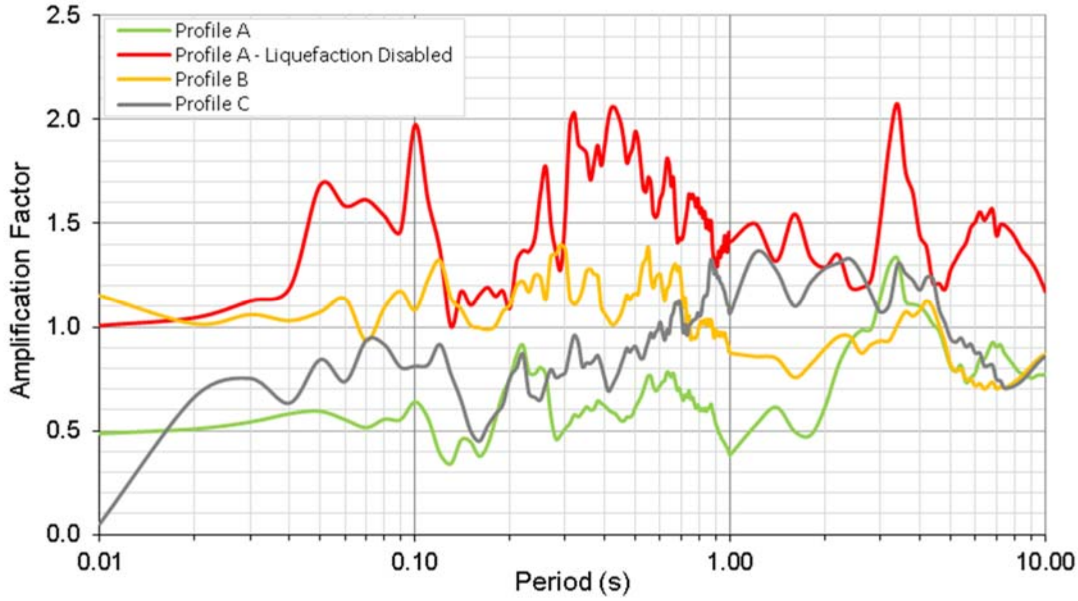

Figure 6.18: Spectral amplifications for Kobe record.

Resultant Spectral Amplification Factors

General trend of the amplification behaviour of each profile is observed to be quite consistent among the records utilized in this study. In Figure 6.19, resultant spectral amplification factors obtained by using the geometric mean of all response spectra are presented.

It is observed from this figure that, the non-liquefiable case of *Profile A* exhibits the highest amplification ratios of about 1.5 times between 0.1 to 1.0 s period. However, liquefied case of the same profile de-amplifies with a ratio of about 0.6. Ratio of these two spectral amplification factors is 2.5, which is significant.

Amplification behaviour of *Profile B* is also quite identical to the non-liquefiable case of *Profile A*. Response at *Profile C* is de-amplified and exhibits a tendency to decrease within an interval between 0.1 and 0.8 s.

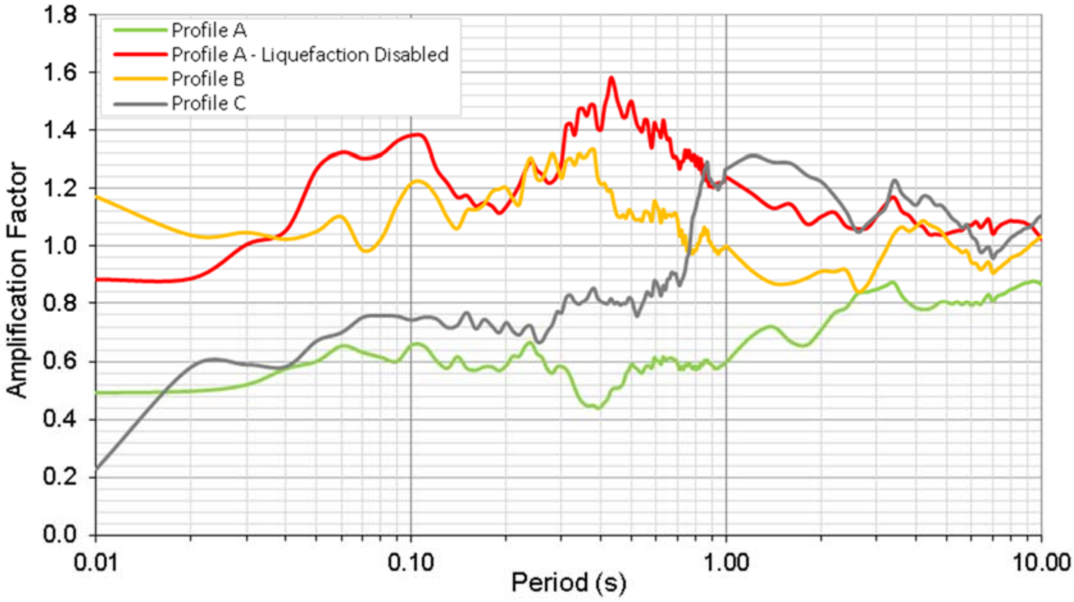

Figure 6.19: Resultant spectral acceleration amplification factors.

CHAPTER 7

SUMMARY AND DISCUSSION OF RESULTS

In this study, relation of the local site effects on damage distribution at the City Centre of Yalova due to 1999 İzmit Earthquake is investigated. The data on building damage were compiled from the damage survey reports prepared after the earthquake. It is supposed that the event with a moment magnitude of 7.4 yielded a peak ground acceleration value about 0.38 g in the City Centre. Liquefaction potential assessed for a number of boreholes reported by CMSP and Kendir (2010). The simplified SPT-based procedure of Youd et al. (2001) is used for assessments and only the sand deposits are considered as liquefiable. One-dimensional nonlinear site response analyses including the effects of pore pressure generation on shear strength are conducted with *Cyclic1D* software by considering three idealized wave-velocity profiles for the study area. Five ground motion records are selected and scaled to represent seismic excitation at the site. Acceleration response spectra and spectral amplification factors are calculated for each of the ground motion records.

Prior to the discussion of results, it should be noted that this study is based on certain assumptions. The data on damage statistics and the reports on in-situ tests are supposed to be error-free. Therefore, the products of this study is depended on the reliability of these documents. There is supporting evidence that the distribution of damage prepared in this study is consistent with the damage map produced by Kendir (2010), using a different survey data. *SPT* blow counts are sensitive to nonstandard procedures, hence need validation with some other possible tests such as *CPT*. The soil profiles used in the dynamic response analyses are generalized under three different profiles.

In addition, it is considered that there is no significant variability in the structural capacities of reinforced concrete buildings that have the same number of stories.

According to the spatial distribution of damage in Figure 4.2, the building-collapse was limited in Bahçelievler and Rüstempaşa Quarters. Most collapsed buildings were located near to Stadium yard of Bahçelievler Quarter and at the south of Rüstempaşa Quarter. The number of collapsed buildings were high in Hacımehmet Basin of Kazım Karabekir Quarter, and in the west of Bağlarbaşı Quarter. The collapsed buildings were also relatively few at the rest of Kazım Karabekir Quarter and at the rest of Bağlarbaşı Quarter.

According to the liquefaction potential map in Figure 5.3, there is no liquefiable layer in Bağlarbaşı and Kazım Karabekir Quarters. Some of the areas of Bahçelievler and Rüstempaşa Quarters are located on a liquefiable deposit. Besides, thickness of the liquefiable layers show significant variability. In addition, the soil deposits investigated in boreholes near to Stadium Yard and Safran River in Bahçelievler Quarter are neither prone to liquefaction, nor involving liquefaction potential for layers thicker than 2 m. The geotechnical database used in this study suggested that the range of SPT blow-counts is from 6 to 25 for most sand layers having liquefaction potential. The estimated post-liquefaction volumetric strains for this SPT blow-count range can reach to 4.5% according to the relationship provided by Ishihara and Yoshimine (1992). The estimated post-liquefaction consolidation settlement can be as high as 9 cm for a 2 m thick sand layer. Whereas, it is observed that the building damage was concentrated near the boreholes that have no or limited liquefaction potential, when damage distribution is superposed on the map of boreholes (Figure 5.4). Almost no damage is observed in areas near the boreholes that involve liquefiable deposits thicker than 2 m.

In order to understand the effect of liquefaction on severity of shaking, *Cyclic1D* software was used. Five scaled ground motions were considered as the rock out-crop motion for the generic velocity profile, namely *Profile A* (Figure 6.3). The spectral ordinates were amplified by factors around 1.5 for the range of periods from 0.1 s to

1.0 s, in the cases that residual pore pressures in deposits were not generated. On the other hand, the cyclic pore pressure generation and consequently liquefaction yields to significant de-amplification in spectral ordinates (by factors around 0.6, as shown in Figure 6.19). These amplification factors are certainly dependent on the presumed model parameters. When these results and the damage reports are considered, it can be said that the liquefaction might have significantly reduced the seismic demand on structures during the 1999 İzmit Earthquake, and might have reduced the proportion of collapsing, if the thickness of liquefiable layer was more than 2 m beneath these buildings. This conclusion is consistent with Figure (10) of Özcep et al. (2014), which shows that heavily damaged zones are almost completely pertinent to the sites having no or limited potential for liquefaction induced settlement. This result is also parallel with the passive isolation effect induced of liquefaction identified by Shibata et al. (1996) for the Hyogoken, Nambu earthquake. Lopez (2002) supported this observation by studying the ground-motion records from three different sites of liquefaction.

According to the spatial damage distribution map, the most collapsed buildings are located on Hacımehmet Plain of Kazım Karabekir Quarter and on Safran River coast of Bağlarbaşı Quarter (Figure 4.2). *Profile C* (Figure 6.3) is selected to represent these sites. It exhibits de-amplification with the similar spectral acceleration amplification ratios, when compared with liquefaction-enabled case of *Profile A. H*owever, this result cannot explain the intensity of collapsed buildings at these sites. Considering the possibility of under-estimation of V_s values of residual formations at this site, profiles with 50% increased shear wave velocities are also analysed for NS components of İzmit Earthquake record. However, no significant change is observed in the site response. Reason of this contrast might be that, one-dimensional model does not cover the basin effects which might increase the seismic demand as reported in previously discussed case histories (e.g., Kawase, 1996; Bielak et al., 1999).

The number of collapsed buildings on the west of Kazım Karabekir and on the east of Bağlarbaşı Quarters, where majority of buildings have 1 to 3 stories, is also limited. Approximate amplification ratio for spectral accelerations is in the range from 1 to 1.2

for the period range from 0.1 s to 0.3 s. Hence, these buildings were less sensitive to site amplification.

CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORK

As a result of this study the following conclusions are reached.

- Spatial damage distribution of reinforced concrete buildings in City of Yalova due to 1999 İzmit Earthquake significantly varied from site to site. The majority of the collapsed buildings were located at Hacımehmet Basin and at the west side of Bağlarbaşı Quarter.

- Different thicknesses of soil layers at various locations of Bahçelievler and Rüstempaşa Quarters might have liquefied during the earthquake. Besides, there is no potential of liquefaction in Kazım Karabekir and Bağlarbaşı Quarters.

- It is concluded that the liquefaction might have reduced seismic demand on the structures at particular locations in the City Centre of Yalova. The numerical simulations with *Profile A* showed a very significant reduction in the spectral amplitudes. The spectral de-amplification factors were estimated to be about 1/2.5 in the range of 0.1 to 1.0 s periods.

- Building damage is limited on the west side of Kazım Karabekir Quarter, and on the east side of Bağlarbaşı Quarter. On the other hand, the number of stories was generally 1 to 3 in these parts of study area. The site response is investigated by considering *Profile B,* and the computed spectral amplitudes observed to be quite identical to those computed by using *Profile A* in the absence of liquefaction. The reason of limited damage might be explained by the limited response amplitudes of low rise buildings.

- The intensity of collapsed buildings on Hacımehmet basin, and on the west side of Bağlarbaşı Quarter cannot be explained with one-dimensional site response analyses. The response of *Profile C* representing the west side of Bağlarbaşı Quarter showed a tendency to decrease amplitudes within in the spectral period range from 0.1 to 0.8 s. One explanation can be the possible two-dimensional basin response during the earthquake.

As a result of this study, the following issues can be recommended for future studies.

- High intensity of building collapse near Safran River cannot be explained with one-dimensional site response analyses. Nonlinear site response with two-dimensional or three-dimensional models should be considered to investigate possible basin effects.

- Idealized soil profiles used in this study can be improved with additional tests on the soil properties for more accurate estimation of seismic demand during the 1999 İzmit Earthquake.

- Relation of liquefaction induced de-amplification behaviour, also called as passive base isolation effect, with liquefied layer depth can be studied further.

- The consequences of soil-structure interaction for buildings on liquefying soils can be analysed, so that structural behaviour on such soils can be interpreted for design recommendations.

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APPENDIX A

THE BOREHOLES USED IN THE STUDY AND ESTIMATED SOIL PARAMETERS

Table A.1: References, UTM Coordinates and ground water levels (*GWL*) of boreholes covered in the study.

ID In This Study	ID At Reference	Reference	X	Y	GWL (m)
A1	ASK-6	CMSP[1]	436319	4502884	0.3
A2	ASK-7	CMSP[1]	436316	4502537	1.6
A3	ASK-8	CMSP[1]	436717	4502727	2.2
A4	ASK-9	CMSP[1]	436724	4502542	2.6
A5	ASK-10	CMSP[1]	436924	4502713	1.9
A6	ASK-11	CMSP[1]	436924	4502525	2.3
A7	ASK-12	CMSP[1]	437132	4502699	1.7
A8	ASK-13	CMSP[1]	437128	4502328	3.7
A9	ASK-14	CMSP[1]	437328	4502775	0.3
A10	ASK-15	CMSP[1]	437422	4502421	3.3
A11	ASK-16	CMSP[1]	437521	4502720	1.7
A12	ASK-17	CMSP[1]	437920	4502715	0.0
A13	ASK-18	CMSP[1]	437911	4502342	2.1
A14	ASK-19	CMSP[1]	438134	4502879	0.5
A15	ASK-20	CMSP[1]	438129	4502722	0.5
A16	ASK-21	CMSP[1]	438131	4502509	2.2
A17	ASK-22	CMSP[1]	438126	4502326	2.5
A18	ASK-24	CMSP[1]	438323	4502718	2.3
A19	ASK-25	CMSP[1]	438316	4502514	2.4
A20	ASK-26	CMSP[1]	438316	4502331	3.3
B1	BSK-1	CMSP[1]	436229	4502388	-
B2	BSK-2	CMSP[1]	436374	4502386	-
B3	BSK-3	CMSP[1]	436532	4502397	-
B4	BSK-4	CMSP[1]	436074	4502283	-
B5	BSK-5	CMSP[1]	436238	4502241	-
B6	BSK-6	CMSP[1]	436527	4502234	-
B7	BSK-7	CMSP[1]	436679	4502248	-
B8	BSK-8	CMSP[1]	436829	4502245	-
B9	BSK-9	CMSP[1]	436971	4502229	-
B10	BSK-10	CMSP[1]	436058	4502096	-
B11	BSK-11	CMSP[1]	436231	4502113	-
B12	BSK-12	CMSP[1]	436383	4502091	-
B13	BSK-13	CMSP[1]	436525	4502091	-
B14	BSK-14	CMSP[1]	436677	4502092	-
B15	BSK-15	CMSP[1]	436829	4502096	-
B16	BSK-16	CMSP[1]	436979	4502092	-
B17	BSK-17	CMSP[1]	436684	4501940	-
B18	BSK-18	CMSP[1]	436824	4501942	-
B19	BSK-19	CMSP[1]	436976	4501945	-

Table A.1: References, UTM Coordinates and ground water levels (*GWL*) of boreholes covered in the study. (Cont'd)

ID In This Study	ID At Reference	Reference	X	Y	GWL (m)
B20	BSK-20	CMSP[1]	436839	4501792	-
B21	BSK-21	CMSP[1]	436988	4501791	-
B22	BSK-22	CMSP[1]	436688	4501637	-
B23	BSK-23	CMSP[1]	436836	4501639	-
B24	BSK-24	CMSP[1]	436984	4501642	-
B25	BSK-25	CMSP[1]	437116	4501646	-
B26	BSK-26	CMSP[1]	436533	4501483	-
B27	BSK-28	CMSP[1]	436833	4501497	-
B28	BSK-29	CMSP[1]	436984	4501499	-
B29	BSK-30	CMSP[1]	436521	4501338	-
B30	BSK-31	CMSP[1]	436673	4501344	-
B31	BSK-32	CMSP[1]	436838	4501347	-
C1	CSK-1	CMSP[1]	437174	4502098	2.9
C2	CSK-2	CMSP[1]	437576	4502082	1.1
C3	CSK-3	CMSP[1]	437951	4501970	1.2
C4	CSK-4	CMSP[1]	437325	4501842	2.0
C5	CSK-5	CMSP[1]	437583	4501823	0.8
C6	CSK-6	CMSP[1]	437151	4501484	3.0
C7	CSK-7	CMSP[1]	437571	4501584	2.3
C8	CSK-8	CMSP[1]	437830	4501586	2.5
C9	CSK-9	CMSP[1]	437008	4501321	2.7
C10	CSK-10	CMSP[1]	437177	4501312	2.6
C11	CSK-11	CMSP[1]	437404	4501318	2.6
C12	CSK-12	CMSP[1]	437825	4501342	2.4
C13	CSK-13	CMSP[1]	437327	4501097	2.6
C14	CSK-14	CMSP[1]	436851	4500893	2.8
C15	CSK-15	CMSP[1]	437073	4500872	2.7
C16	CSK-16	CMSP[1]	437325	4500606	2.0
C17	CSK-17	CMSP[1]	436890	4500365	2.9
C18	CSK-18	CMSP[1]	437201	4500218	1.3
C19	CSK-19	CMSP[1]	436922	4500119	3.0
C20	CSK-20	CMSP[1]	437203	4499967	1.1
D1	DSK-13	CMSP[1]	438478	4501948	-
D2	DSK-18	CMSP[1]	438628	4501800	-
D3	DSK-19	CMSP[1]	438775	4501796	-
D4	DSK-23	CMSP[1]	438175	4501647	-
D5	DSK-24	CMSP[1]	438320	4501647	-
D6	DSK-25	CMSP[1]	438478	4501645	-
D7	DSK-26	CMSP[1]	438785	4501650	-

Table A.1: References, UTM Coordinates and ground water levels (*GWL*) of boreholes covered in the study. (Cont'd)

ID In This Study	ID At Reference	Reference	X	Y	GWL (m)
D8	DSK-30	CMSP[1]	438027	4501492	-
D9	DSK-31	CMSP[1]	438179	4501497	-
D10	DSK-32	CMSP[1]	438325	4501493	-
D11	DSK-33	CMSP[1]	438483	4501498	-
D12	DSK-34	CMSP[1]	438635	4501502	-
D13	DSK-35	CMSP[1]	438778	4501487	-
D14	DSK-38	CMSP[1]	438029	4501338	-
D15	DSK-39	CMSP[1]	438328	4501340	-
D16	DSK-40	CMSP[1]	438487	4501338	-
D17	DSK-41	CMSP[1]	438630	4501347	-
D18	DSK-44	CMSP[1]	438025	4501185	-
D19	DSK-45	CMSP[1]	438177	4501190	-
D20	DSK-46	CMSP[1]	438470	4501185	-
D21	DSK-47	CMSP[1]	438610	4501187	-
D22	DSK-50	CMSP[1]	438179	4501053	-
D23	DSK-55	CMSP[1]	437724	4500900	-
D24	DSK-56	CMSP[1]	437877	4500897	-
D25	DSK-57	CMSP[1]	438177	4500902	-
D26	DSK-58	CMSP[1]	438483	4500895	-
D27	DSK-62	CMSP[1]	437577	4500739	-
D28	DSK-63	CMSP[1]	437725	4500747	-
D29	DSK-64	CMSP[1]	437866	4500735	-
D30	DSK-65	CMSP[1]	438182	4500739	-
D31	DSK-66	CMSP[1]	438333	4500740	-
D32	DSK-70	CMSP[1]	437655	4500597	-
D33	DSK-71	CMSP[1]	438024	4500595	-
D34	DSK-72	CMSP[1]	438164	4500586	-
D35	DSK-75	CMSP[1]	437574	4500441	-
D36	DSK-76	CMSP[1]	437866	4500436	-
F1	SK-6	Kendir (2010)	437017	4502767	2.0
F2	SK-9	Kendir (2010)	437203	4502575	2.7
F3	SK-8	Kendir (2010)	437191	4502429	2.3
F4	SK-7	Kendir (2010)	437272	4502307	2.0
F5	SK-11	Kendir (2010)	437408	4502535	1.4
F6	SK-13	Kendir (2010)	437575	4502431	2.6
F7	SK-15	Kendir (2010)	437640	4502789	1.0[2]

[1]*CMSP* stands for *City Microzonation Survey Report Base to Master Plan of 1150 Hectare Area of Yalova City (2015).*

[2]Assumed value.

Table A.2: Estimated soil parameters by using SPT data.

SPT Data				Estimated Parameters		
Borehole ID	DEPTH (m)	USCS	N_m	V_s	c_u (kPa)	ϕ (degree)
ASK-6	4.50-4.95	SM	36	272	-	37
ASK-6	6.00-6.45	SM	16	212	-	32
ASK-6	7.50-7.95	SM	16	212	-	32
ASK-6	9.00-9.45	SM	5	148	-	29
ASK-6	10.50-10.95	CL	27	249	-	35
ASK-6	12.00-12.45	SW-SM	50	301	-	41
ASK-6	13.50-13.95	SW-SM	44	290	-	39
ASK-6	15.50-15.95	CL	35	270	210	-
ASK-6	16.50-16.95	CL	39	279	234	-
ASK-6	18.00-18.45	CH	R	-	-	-
ASK-6	19.50-19.95	CH	R	-	-	-
ASK-7	1.50-1.95	SM	8	171	-	-
ASK-7	3.00-3.45	SM	23	237	-	34
ASK-7	4.50-4.95	SM	24	240	-	34
ASK-7	6.00-6.45	SM	14	203	-	31
ASK-7	7.50-7.95	SM	32	263	-	36
ASK-7	9.00-9.45	SM	20	227	-	33
ASK-7	10.50-10.95	CH	14	203	84	-
ASK-7	12.00-12.45	CH	22	234	132	-
ASK-7	13.50-13.95	CH	51	303	306	-
ASK-7	15.50-15.95	CH	34	268	204	-
ASK-7	16.50-16.95	CH	R	-	-	-
ASK-7	18.00-18.45	CH	R	-	-	-
ASK-7	19.50-19.95	CH	R	-	-	-
ASK-8	1.50-1.95	GP-GM	15	208	-	31
ASK-8	3.00-3.45	GP-GM	31	260	-	36
ASK-8	4.50-4.95	GP-GM	26	246	-	35
ASK-8	6.00-6.45	GP-GM	25	243	-	34
ASK-8	7.50-7.95	GP-GM	2	111	-	28
ASK-8	9.00-9.45	GP-GM	27	249	-	35
ASK-8	10.50-10.95	CH	40	281	240	-
ASK-8	12.00-12.45	CH	R	-	-	-
ASK-8	13.50-13.95	CH	R	-	-	-
ASK-8	15.50-15.95	CH	R	-	-	-
ASK-8	16.50-16.95	CH	R	-	-	-
ASK-8	18.00-18.45	CH	R	-	-	-
ASK-8	19.50-19.95	CH	R	-	-	-
ASK-9	1.50-1.95	SM	17	216	-	32
ASK-9	3.00-3.45	SM	13	199	-	31
ASK-9	4.50-4.95	SM	14	203	-	31
ASK-9	6.00-6.45	SM	18	220	-	32
ASK-9	7.50-7.95	CH	17	216	102	-
ASK-9	9.00-9.45	CH	25	243	150	-
ASK-9	10.50-10.95	CH	18	220	108	-
ASK-9	12.00-12.45	CH	28	252	168	-
ASK-9	13.50-13.95	CH	24	240	144	-
ASK-9	15.00-15.45	CH	39	279	234	-
ASK-9	16.50-16.95	CH	38	277	228	-
ASK-9	18.00-18.45	CH	43	288	258	-
ASK-9	19.50-19.95	CH	54	309	324	-
ASK-10	1.50-1.95	SP	23	237	138	-
ASK-10	3.00-3.45	SP	26	246	156	-
ASK-10	4.50-4.95	SP	37	275	222	-
ASK-10	6.00-6.45	SP	41	284	246	-
ASK-10	7.50-7.95	CH	43	288	258	-
ASK-10	9.00-9.45	CH	46	294	276	-
ASK-10	10.50-10.95	CH	51	303	306	-
ASK-10	12.00-12.45	CH	54	309	324	-
ASK-10	13.50-13.95	CH	71	336	426	-
ASK-10	15.00-15.45	CH	77	344	462	-

Table A.2: Estimated soil parameters by using SPT data (Cont'd).

SPT Data				Estimated Parameters		
Borehole ID	DEPTH (m)	USCS	N_m	V_s	c_u (kPa)	ϕ (degree)
ASK-10	16.50-16.95	CH	86	356	516	-
	18.00-18.45		R	-	-	-
	19.50-19.95		R	-	-	-
ASK-11	1.50-1.95	SP	24	240	-	34
	3.00-3.45		35	270	-	37
	4.50-4.95	SM	44	290	-	39
	6.00-6.45		26	246	-	35
	7.50-7.95		23	237	-	34
	9.00-9.45		24	240	-	34
	10.50-10.95	CH	30	257	180	-
	12.00-12.45		35	270	210	-
	13.50-13.95		41	284	246	-
	15.00-15.45		44	290	264	-
	16.50-16.95		45	292	270	-
	18.00-18.45		49	300	294	-
	19.50-19.95		56	312	336	-
ASK-12	1.50-1.95	SM	17	216	-	32
	3.00-3.45		14	203	-	31
	4.50-4.95	SW-SM	14	203	-	31
	6.00-6.45		27	249	-	35
	7.50-7.95	CH	20	227	120	-
	9.00-9.45		R	-	-	-
	10.50-10.95		R	-	-	-
	12.00-12.45		R	-	-	-
	13.50-13.95	CH	R	-	-	-
	15.00-15.45		R	-	-	-
	16.50-16.95		R	-	-	-
ASK-13	1.50-1.95	SM	37	275	-	-
	3.00-3.45		36	272	-	-
	4.50-4.95		40	281	-	-
	6.00-6.45	CL	44	290	264	-
	7.50-7.95		44	290	264	-
	9.00-9.45		54	309	324	-
	10.50-10.95		49	300	294	-
	12.00-12.45		48	298	288	-
	13.50-13.95		51	303	306	-
	15.00-15.45		61	321	366	-
	16.50-16.95		62	322	372	-
	18.00-18.45		72	337	432	-
	19.50-19.95	CH	73	339	438	-
ASK-14	1.50-1.95		R	-	-	-
	3.00-3.45		R	-	-	-
	4.50-4.95	SP-SM	31	260	-	36
	6.00-6.45		33	265	-	36
	7.50-7.95	SM	26	246	-	35
	9.00-9.45	CH	28	252	168	-
	10.50-10.95		57	314	342	-
	12.00-12.45		54	309	324	-
	13.50-13.95		60	319	360	-
	15.00-15.45		63	324	378	-
	16.50-16.95		61	321	366	-
	18.00-18.45		76	343	456	-
	19.50-19.95		84	354	504	-
ASK-15	1.50-1.95		14	203	84	-
	3.00-3.45	SP-SM	19	224	-	33
	4.50-4.95		36	272	-	37
	6.00-6.45	SM	10	183	-	30
	7.50-7.95		13	199	78	-
	9.00-9.45		18	220	108	-
	10.50-10.95		24	240	144	-

Table A.2: Estimated soil parameters by using SPT data (Cont'd).

SPT Data				Estimated Parameters		
Borehole ID	DEPTH (m)	USCS	N_m	V_s	c_u (kPa)	ϕ (degree)
ASK-15	12.00-12.45	SM	30	257	180	-
	13.50-13.95	CH	R	-	-	-
	15.00-15.45		R	-	-	-
	16.50-16.95		R	-	-	-
	18.00-18.45		R	-	-	-
	19.50-19.95		R	-	-	-
	21.00-21.45		R	-	-	-
ASK-16	1.50-1.95		16	212	-	-
	3.00-3.45	SM	23	237	-	34
	4.50-4.95		16	212	-	32
	6.00-6.45		22	234	-	33
	7.50-7.95		42	286	-	39
	9.00-9.45	CL	79	347	474	-
	10.50-10.95	CH	R	-	-	-
	12.00-12.45		R	-	-	-
	13.50-13.95		R	-	-	-
	15.00-15.45		R	-	-	-
	16.50-16.95		R	-	-	-
ASK-17	1.50-1.95		22	234	132	-
	3.00-3.45		37	275	222	-
	4.50-4.95	SP	33	265	-	36
	6.00-6.45	SP-SM	24	240	-	34
	7.50-7.95		24	240	-	34
	9.00-9.45		26	246	-	35
	10.50-10.95		28	252	-	35
	12.00-12.45		30	257	-	36
	13.50-13.95		30	257	-	36
	15.00-15.45		32	263	-	36
	16.50-16.95	SP-SM	33	265	198	-

SPT Data				Estimated Parameters		
Borehole ID	DEPTH (m)	USCS	N_m	V_s	c_u (kPa)	ϕ (degree)
ASK-17	18.00-18.45	CH	4	138	24	-
	19.50-19.95		7	164	42	-
	21.00-21.45		5	148	30	-
	24.00-24.45		4	138	24	-
	27.00-27.45		31	260	186	-
	30.00-30.45		25	243	150	-
	33.00-33.45		41	284	246	-
	36.00-36.45		50	301	300	-
	39.00-39.45		46	294	276	-
ASK-18	1.50-1.95		4	138	-	-
	3.00-3.45		R	-	-	-
	4.50-4.95	SM	48	298	-	40
	6.00-6.45	SW-SM	39	279	-	38
	7.50-7.95		R	-	-	-
	9.00-9.45		R	-	-	-
	10.50-10.95		58	316	-	43
	12.00-12.45		11	189	-	30
	13.50-13.95	CH	8	171	48	-
	16.50-16.95		4	138	24	-
	18.00-18.45		6	157	36	-
	19.50-19.95		5	148	30	-
	21.00-21.45		6	157	36	-
	22.50-22.95		6	157	36	-
	24.00-24.45		8	171	48	-
	25.50-25.95		10	183	60	-
	27.00-27.45		16	212	96	-
	28.50-28.95		10	183	60	-
	30.00-30.45		12	194	72	-
	31.50-31.95		14	203	84	-
	33.00-33.45	GM	R	-	-	-
	35.50-35.95		R	-	-	-

Table A.2: Estimated soil parameters by using SPT data (Cont'd).

SPT Data				Estimated Parameters		
Borehole ID	DEPTH (m)	USCS	N_m	V_s	c_u (kPa)	ϕ (degree)
ASK-18	36.00-36.45	CH	26	246	156	-
ASK-18	37.50-37.95	CH	24	240	144	-
ASK-18	40.00-40.45	CH	36	272	216	-
ASK-19	1.50-1.95		20	227	-	33
ASK-19	3.00-3.45		34	268	-	37
ASK-19	4.50-4.95	SP-SM	36	272	-	37
ASK-19	6.00-6.45	SP	20	227	-	33
ASK-19	7.50-7.95	SP	22	234	-	33
ASK-19	9.00-9.45	SP	25	243	-	34
ASK-19	10.50-10.95	CL	6	157	36	-
ASK-19	12.00-12.45	CL	18	220	108	-
ASK-19	13.50-13.95	CL	12	194	72	-
ASK-19	15.00-15.45	SP-SM	17	216	-	32
ASK-19	16.50-16.95	SP-SM	18	220	-	32
ASK-19	18.00-18.45	SP-SM	20	227	-	33
ASK-19	19.50-19.95	SP-SM	24	240	-	34
ASK-19	21.00-21.45	SP-SM	26	246	-	35
ASK-19	24.00-24.45	CH	27	249	162	-
ASK-19	27.00-27.45	CH	7	164	42	-
ASK-19	30.00-30.45	CH	10	183	60	-
ASK-19	33.00-33.45	CH	9	177	54	-
ASK-19	36.00-36.45	CH	12	194	72	-
ASK-19	39.00-39.45	CH	10	183	60	-
ASK-19	42.00-42.45	CH	10	183	60	-
ASK-19	45.00-45.45	CH	14	203	84	-
ASK-19	48.00-48.45	CH	32	263	192	-
ASK-19	51.00-51.45	CH	63	324	378	-
ASK-20	1.50-1.95		R	-	-	-
ASK-20	3.00-3.45	SW-SM	29	255	-	35
ASK-20	4.50-4.95	SP-SM	7	164	-	29
ASK-20	6.00-6.45	SP-SM	21	231	-	33
ASK-20	7.50-7.95	SP-SM	18	220	-	32
ASK-20	10.50-10.95	SP-SM	18	220	-	32
ASK-20	12.00-12.45	SP-SM	60	319	-	43
ASK-20	13.50-13.95	SP-SM	87	358	-	49
ASK-20	15.00-15.45	SP-SM	49	300	-	41
ASK-20	16.50-16.95	SP-SM	48	298	-	40
ASK-20	18.00-18.45	CL	24	240	144	-
ASK-20	19.50-19.95	CL	30	257	180	-
ASK-20	22.50-22.95	CL	14	203	84	-
ASK-20	25.50-25.95	CL	31	260	186	-
ASK-20	28.50-28.95	CL	32	263	192	-
ASK-20	31.50-31.95	CL	22	234	132	-
ASK-20	34.50-34.95	CL	31	260	186	-
ASK-20	37.50-37.95	CL	35	270	210	-
ASK-20	40.50-40.95	CL	18	220	108	-
ASK-20	43.50-43.95	CL	84	354	504	-
ASK-20	46.50-46.95	CH	R	-	-	-
ASK-20	48.00-48.45	CH	R	-	-	-
ASK-21	1.50-1.95	SM	28	252	-	35
ASK-21	3.00-3.45	SM	33	265	-	36
ASK-21	4.50-4.95	SM	37	275	-	37
ASK-21	6.00-6.45	SM	27	249	162	-
ASK-21	7.50-7.95	SM	31	260	186	-
ASK-21	9.00-9.45	CL	31	260	186	-
ASK-21	10.50-10.95	CL	30	257	180	-
ASK-21	12.00-12.45	CL	27	249	162	-
ASK-21	13.50-13.95	CL	14	203	84	-
ASK-21	15.00-15.45	CL	9	177	54	-

Table A.2: Estimated soil parameters by using SPT data (Cont'd).

SPT Data				Estimated Parameters		
Borehole ID	DEPTH (m)	USCS	N_m	V_s	c_u (kPa)	ϕ (degree)
ASK-21	16.50-16.95	CL	8	171	48	-
	18.00-18.45		5	148	30	-
	19.50-19.95		6	157	36	-
	21.00-21.45		7	164	42	-
	24.00-24.45		4	138	24	-
	27.00-27.45	SM	31	260	186	-
	30.00-30.45	CH	38	277	228	-
	33.00-33.45		46	294	276	-
	36.00-36.45		52	305	312	-
	39.00-39.45		65	327	390	-
ASK-22	1.50-1.95		6	157	36	-
	3.50-3.95		22	234	132	-
	4.50-4.95	GP-GM	22	234	132	-
	6.00-6.45	SM	21	231	126	-
	7.50-7.95	CL	7	164	42	-
	9.00-9.45		4	138	24	-
	10.50-10.95		6	157	36	-
	12.00-12.45		5	148	30	-
	13.50-13.95		4	138	24	-
	15.00-15.45		4	138	24	-
	16.50-16.95		6	157	36	-
	18.00-18.45		5	148	30	-
	19.50-19.95		30	257	180	-
	21.00-21.45	CH	34	268	204	-
	24.00-24.45		35	270	210	-
	27.00-27.45		35	270	210	-
ASK-24	1.50-1.95	SP-SM	17	216	-	32
	3.00-3.45		21	231	-	33
	4.50-4.95		21	231	-	33
	6.00-6.45		17	216	-	32
	7.50-7.95	CL	29	255	174	-

SPT Data				Estimated Parameters		
Borehole ID	DEPTH (m)	USCS	N_m	V_s	c_u (kPa)	ϕ (degree)
ASK-24	9.00-9.45	SM	15	208	-	31
	10.50-10.95		19	224	-	33
	12.00-12.45		30	257	-	36
	13.50-13.95	SP-SM	25	243	-	34
	15.00-15.45	SP	22	234	-	33
	16.50-16.95		33	265	-	36
	18.00-18.45		33	265	-	36
	19.50-19.95		32	263	-	36
	21.00-21.45		25	243	-	34
	24.00-24.45	CH	29	255	174	-
	27.00-27.45		18	220	108	-
	30.00-30.45		16	212	96	-
	33.00-33.45		16	212	96	-
	36.00-36.45		37	275	222	-
	39.00-39.45		R	-	-	-
ASK-25	1.50-1.95		18	220	108	-
	3.00-3.45		25	243	150	-
	4.50-4.95	SM	36	272	-	37
	6.00-6.45	SP	38	277	-	38
	7.50-7.95	CH	26	246	156	-
	9.00-9.45		15	208	90	-
	10.50-10.95		20	227	120	-
	12.00-12.45		21	231	126	-
	13.50-13.95		23	237	138	-
	15.00-15.45		23	237	138	-
	16.50-16.95		24	240	144	-
	18.00-18.45		27	249	162	-
	19.50-19.95		26	246	156	-
	21.00-21.45		29	255	174	-
	24.00-24.45		33	265	198	-
	27.00-27.45		29	255	174	-

Table A.2: Estimated soil parameters by using SPT data (Cont'd).

SPT Data				Estimated Parameters		
Borehole ID	DEPTH (m)	USCS	N_m	V_s	c_u (kPa)	ϕ (degree)
ASK-26	1.50-1.95	CL	14	203	84	-
	3.50-3.95	SM	40	281	-	38
	4.50-4.95		41	284	-	38
	6.00-6.45	CL	46	294	276	-
	7.50-7.95		22	234	132	-
	9.00-9.45	CH	25	243	150	-
	10.50-10.95		29	255	174	-
	12.00-12.45		31	260	186	-
	13.50-13.95		28	252	168	-
	15.00-15.45		29	255	174	-
	16.50-16.95		25	243	150	-
	18.00-18.45		32	263	192	-
	19.50-19.95		41	284	246	-
	21.00-21.45		43	288	258	-
	24.00-24.45		49	300	294	-
	27.00-27.45		76	343	456	-
BSK-1	1.50-1.95		18	220	-	-
	3.50-3.95	CH	26	246	156	-
	4.50-4.95		34	268	204	-
	6.50-6.95		33	265	198	-
	7.50-7.95		41	284	246	-
	9.15-9.60		52	305	312	-
	10.50-10.95		42	286	252	-
	12.50-12.95		R	-	-	-
	13.50-13.95		R	-	-	-
	15.50-15.95		50	301	300	-
	16.50-16.95		60	319	360	-
	18.00-18.45		54	309	324	-
	19.50-19.95		64	325	384	-
BSK-2	1.50-1.95	CL	14	203	84	-
	3.00-3.45		24	240	144	-
	4.50-4.95	CH	32	263	192	-
	6.00-6.45		36	272	216	-
	7.50-7.95		40	281	240	-
	9.00-9.45		51	303	306	-
	10.50-10.95		59	317	354	-
	12.00-12.45		62	322	372	-
	13.50-13.95		62	322	372	-
	15.00-15.45		66	328	396	-
	16.50-16.95		81	350	486	-
	18.00-18.45		R	-	-	-
	19.50-19.95		R	-	-	-
BSK-3	1.50-1.95	CH	11	189	66	-
	3.50-3.95		18	220	108	-
	4.50-4.95		15	208	90	-
	6.50-6.95		21	231	126	-
	7.50-7.95		39	279	234	-
	9.00-9.45		57	314	342	-
	10.50-10.95		63	324	378	-
	12.00-12.45		75	342	450	-
	13.50-13.95		81	350	486	-
	15.00-15.45		69	333	414	-
	16.50-16.95		74	340	444	-
	18.00-18.45		76	343	456	-
	19.50-19.95		77	344	462	-
BSK-4	1.50-1.95	CH	26	246	156	-
	3.00-3.45		23	237	138	-
	5.00-5.45		29	255	174	-
	6.00-6.45		32	263	192	-

Table A.2: Estimated soil parameters by using SPT data (Cont'd).

SPT Data				Estimated Parameters		
Borehole ID	DEPTH (m)	USCS	N_m	V_s	c_u (kPa)	ϕ (degree)
BSK-4	7.50-7.95	CH	34	268	204	-
	9.50-9.95		35	270	210	-
	10.50-10.95		39	279	234	-
	12.00-12.45		R	-	-	-
	13.50-13.95		R	-	-	-
	15.00-15.45		R	-	-	-
	16.50-16.95		R	-	-	-
	18.00-18.45		R	-	-	-
	19.50-19.95		R	-	-	-
BSK-5	1.50-1.95	CH	13	199	78	-
	3.50-3.95		11	189	66	-
	4.50-4.95		17	216	102	-
	6.50-6.95	SM	8	171	48	-
	7.50-7.95	CH	23	237	138	-
	9.50-9.95	CL	59	317	354	-
	10.50-10.95	CH	52	305	312	-
	12.50-12.95		67	330	402	-
	13.50-13.95		44	290	264	-
	15.50-15.95		38	277	228	-
	16.50-16.95		45	292	270	-
	18.00-18.45		58	316	348	-
BSK-6	1.50-1.95	CH	10	183	60	-
	3.00-3.45		14	203	84	-
	5.00-5.45		15	208	90	-
	6.50-6.95		12	194	72	-
	7.50-7.95		18	220	108	-
	9.50-9.95	CL	31	260	186	-
	10.50-10.95	CH	40	281	240	-
	12.50-12.95		56	312	336	-
	13.50-13.95		73	339	438	-

SPT Data				Estimated Parameters		
Borehole ID	DEPTH (m)	USCS	N_m	V_s	c_u (kPa)	ϕ (degree)
BSK-6	15.00-15.45	CH	40	281	240	-
	16.50-16.95		51	303	306	-
	18.00-18.45		66	328	396	-
	19.50-19.95		R	-	-	-
BSK-7	1.50-1.95	CH	13	199	78	-
	3.50-3.95		17	216	102	-
	4.50-4.95		17	216	102	-
	6.50-6.95		18	220	108	-
	7.50-7.95		21	231	126	-
	9.50-9.95		30	257	180	-
	10.50-10.95	CL	33	265	198	-
	12.00-12.45		37	275	222	-
	13.50-13.95		50	301	300	-
	15.00-15.45		56	312	336	-
	16.50-16.95		58	316	348	-
	18.00-18.45		71	336	426	-
	19.50-19.95	CH	R	-	-	-
BSK-8	2.00-2.45	CL	14	203	84	-
	3.00-3.45		13	199	78	-
	5.00-5.45		18	220	108	-
	6.00-6.45		10	183	60	-
	7.50-7.95		23	237	138	-
	9.00-9.45		29	255	174	-
	11.00-11.45	CH	54	309	324	-
	12.00-12.45		63	324	378	-
	13.50-13.95		58	316	348	-
	15.00-15.45		59	317	354	-
	16.50-16.95		56	312	336	-
	18.00-18.45		52	305	312	-
	19.50-19.95		R	-	-	-

Table A.2: Estimated soil parameters by using SPT data (Cont'd).

SPT Data				Estimated Parameters		
Borehole ID	DEPTH (m)	USCS	N_m	V_s	c_u (kPa)	ϕ (degree)
BSK-9	1.50-1.95	CL	15	208	90	-
	3.50-3.95		18	220	108	-
	4.50-4.95		35	270	210	-
	6.50-6.95		41	284	246	-
	7.50-7.95		50	301	300	-
	9.00-9.45		52	305	312	-
	10.50-10.95		60	319	360	-
	12.00-12.45		59	317	354	-
	13.50-13.95		62	322	372	-
	15.00-15.45		63	324	378	-
	16.50-16.95		71	336	426	-
	18.00-18.45	CH	R	-	-	-
	19.50-19.95		R	-	-	-
BSK-10	1.50-1.95	CL	13	199	78	-
	3.50-3.95		16	212	96	-
	4.50-4.95		21	231	126	-
	6.50-6.95		24	240	144	-
	7.50-7.95		23	237	138	-
	9.00-9.45	CH	34	268	204	-
	10.50-10.95		39	279	234	-
	12.00-12.45		35	270	210	-
	13.50-13.95		46	294	276	-
	15.00-15.45		46	294	276	-
	16.50-16.95		50	301	300	-
	18.00-18.45		54	309	324	-
	19.50-19.95		57	314	342	-
BSK-11	1.50-1.95	CH	6	157	36	-
	3.50-3.95		25	243	150	-
	4.50-4.95		24	240	144	-
	6.50-6.95		28	252	168	-

SPT Data				Estimated Parameters		
Borehole ID	DEPTH (m)	USCS	N_m	V_s	c_u (kPa)	ϕ (degree)
BSK-11	7.50-7.95	CH	39	279	234	-
	9.35-9.80		53	307	318	-
	10.50-10.95		75	342	450	-
	12.40-12.85		R	-	-	-
	13.50-13.95		R	-	-	-
	15.00-15.45		R	-	-	-
	16.50-16.95		R	-	-	-
	18.00-18.45		R	-	-	-
	19.50-19.95		R	-	-	-
BSK-12	1.50-1.95	CH	10	183	60	-
	3.50-3.95		16	212	96	-
	4.50-4.95		23	237	138	-
	6.50-6.95		37	275	222	-
	7.50-7.95		26	246	156	-
	9.50-9.95		44	290	-	39
	10.50-10.95		48	298	-	40
	12.50-12.95		48	298	-	40
	13.50-13.95		47	296	-	40
	15.50-15.95		50	301	-	41
	16.50-16.95		74	340	-	46
	18.00-18.45		73	339	-	46
	19.50-19.95		85	355	-	49
BSK-13	1.50-1.95	CH	14	203	84	-
	3.50-3.95		18	220	108	-
	4.50-4.95		24	240	144	-
	6.00-6.45		27	249	162	-
	8.00-8.45		33	265	198	-
	9.50-9.95		42	286	252	-
	10.50-10.95		37	275	222	-
	12.50-12.95		47	296	282	-

Table A.2: Estimated soil parameters by using SPT data (Cont'd).

SPT Data				Estimated Parameters		
Borehole ID	DEPTH (m)	USCS	N_m	V_s	c_u (kPa)	ϕ (degree)
BSK-13	14.00-14.45	CH	62	322	372	-
	15.00-15.45		28	252	168	-
	16.50-16.95		60	319	360	-
	18.00-18.45		R	-	-	-
	19.50-19.95		R	-	-	-
BSK-14	1.50-1.95	CL	16	212	96	-
	3.50-3.95		16	212	96	-
	4.50-4.95		17	216	102	-
	6.50-6.95	CH	23	237	138	-
	7.50-7.95		31	260	186	-
	9.00-9.45		25	243	150	-
	10.50-10.95		27	249	162	-
	12.00-12.45		36	272	216	-
	13.50-13.95		45	292	270	-
	15.00-15.45		47	296	282	-
	16.50-16.95		65	327	390	-
	18.00-18.45		R	-	-	-
	19.50-19.95		R	-	-	-
BSK-15	0.58	CH	21	231	126	-
	3.50-3.95		22	234	132	-
	4.50-4.95		28	252	168	-
	6.50-6.95		26	246	156	-
	7.50-7.95		25	243	150	-
	9.00-9.45		43	288	258	-
	10.50-10.95		46	294	276	-
	12.50-12.95		43	288	258	-
	13.50-13.95		60	319	360	-
	15.00-15.45		R	-	-	-
	16.50-16.95		R	-	-	-
	18.00-18.45		R	-	-	-
	19.50-19.95		R	-	-	-
BSK-16	1.50-1.95	CL	9	177	54	-
	3.50-3.95		12	194	72	-
	4.50-4.95		17	216	102	-
	6.50-6.95		19	224	114	-
	7.50-7.95		31	260	186	-
	9.00-9.45		42	286	252	-
	10.50-10.95		59	317	354	-
	12.00-12.45		66	328	396	-
	13.50-13.95		67	330	402	-
	15.00-15.45		69	333	414	-
	16.50-16.95	CH	75	342	450	-
	18.00-18.45		R	-	-	-
	19.50-19.95		R	-	-	-
BSK-17	2.00-2.45	CH	16	212	96	-
	3.00-3.45		20	227	120	-
	4.50-4.95		23	237	138	-
	6.50-6.95		28	252	168	-
	7.50-7.95		33	265	198	-
	9.00-9.45		47	296	282	-
	10.50-10.95		54	309	324	-
	12.50-12.95		67	330	402	-
	13.50-13.95		71	336	426	-
	15.00-15.45		65	327	390	-
	16.50-16.95		74	340	444	-
	18.00-18.45		84	354	504	-
	19.50-19.95		88	359	528	-
BSK-18	1.50-1.95	CH	17	216	102	-
	3.50-3.95		20	227	120	-
	4.50-4.95		22	234	132	-
	6.50-6.95		27	249	162	-

Table A.2: Estimated soil parameters by using SPT data (Cont'd).

SPT Data				Estimated Parameters		
Borehole ID	DEPTH (m)	USCS	N_m	V_s	c_u (kPa)	ϕ (degree)
BSK-18	7.50-7.95	CH	25	243	150	-
	9.00-9.45		31	260	186	-
	10.50-10.95		34	268	204	-
	12.00-12.45		34	268	204	-
	13.50-13.95		40	281	240	-
	15.00-15.45		46	294	276	-
	16.50-16.95		51	303	306	-
	18.00-18.45		R	-	-	-
	19.50-19.95		R	-	-	-
BSK-19	1.50-1.95	CH	12	194	72	-
	3.00-3.45		16	212	96	-
	5.00-5.45		20	227	120	-
	6.00-6.45	CL	28	252	168	-
	8.00-8.45		21	231	126	-
	9.00-9.45		28	252	168	-
	10.50-10.95		26	246	156	-
	12.50-12.95		28	252	168	-
	13.50-13.95	CH	25	243	150	-
	15.00-15.45		50	301	300	-
	16.50-16.95		51	303	306	-
	18.00-18.45		R	-	-	-
	19.50-19.95		R	-	-	-
BSK-20	1.50-1.95	CH	14	203	84	-
	3.50-3.95		16	212	96	-
	4.50-4.95		19	224	114	-
	6.00-6.45		24	240	144	-
	7.50-7.95		25	243	150	-
	9.50-9.95		55	310	330	-
	10.50-10.95		55	310	330	-
	12.00-12.45		64	325	384	-

SPT Data				Estimated Parameters		
Borehole ID	DEPTH (m)	USCS	N_m	V_s	c_u (kPa)	ϕ (degree)
BSK-20	14.00-14.45	CH	64	325	384	-
	15.00-15.45		72	337	432	-
	16.50-16.95		65	327	390	-
	18.00-18.45		72	337	432	-
	19.50-19.95		80	349	480	-
BSK-21	1.50-1.95	CL	8	171	48	-
	3.50-3.95		11	189	66	-
	4.50-4.95		10	183	60	-
	6.50-6.95		24	240	-	34
	7.50-7.95		23	237	-	34
	9.00-9.45		33	265	198	-
	11.00-11.45		40	281	240	-
	12.00-12.45	CH	39	279	234	-
	13.50-13.95		49	300	294	-
	15.00-15.45		R	-	-	-
	16.50-16.95		75	342	450	-
	18.00-18.45		R	-	-	-
	19.50-19.95		R	-	-	-
BSK-22	2.00-2.45	CH	17	216	102	-
	3.00-3.45		19	224	114	-
	4.50-4.95		21	231	126	-
	6.50-6.95		22	234	132	-
	7.50-7.95		20	227	120	-
	9.00-9.45		21	231	126	-
	11.00-11.45		30	257	180	-
	12.00-12.45		31	260	186	-
	13.50-13.95		20	227	120	-
	15.00-15.45		22	234	132	-
	16.50-16.95		38	277	228	-
	18.00-18.45		56	312	336	-
	19.50-19.95		R	-	-	-

Table A.2: Estimated soil parameters by using SPT data (Cont'd).

SPT Data				Estimated Parameters		
Borehole ID	DEPTH (m)	USCS	N_m	V_s	c_u (kPa)	ϕ (degree)
BSK-23	1.50-1.95	CL	16	212	96	-
	3.50-3.95		17	216	102	-
	4.50-4.95		17	216	102	-
	6.50-6.95		14	203	84	-
	7.50-7.95		25	243	150	-
	9.00-9.45		27	249	162	-
	10.50-10.95		29	255	174	-
	12.00-12.45		35	270	210	-
	13.50-13.95		39	279	234	-
	15.00-15.45	CH	49	300	294	-
	16.50-16.95		64	325	384	-
	18.00-18.45		R	-	-	-
	19.50-19.95		R	-	-	-
BSK-24	1.50-1.95	CH	20	227	120	-
	3.00-3.45		22	234	132	-
	5.00-5.45		24	240	144	-
	6.00-6.45		23	237	138	-
	8.00-8.45		26	246	156	-
	9.00-9.45		32	263	192	-
	10.50-10.95		42	286	252	-
	12.00-12.45		45	292	270	-
	13.50-13.95		50	301	300	-
	15.00-15.45		57	314	342	-
	16.50-16.95		67	330	402	-
	18.00-18.45		R	-	-	-
	19.50-19.95		R	-	-	-
BSK-25	1.50-1.95	CL	12	194	72	-
	3.50-3.95		14	203	84	-
	4.50-4.95		20	227	120	-
	6.00-6.45		26	246	156	-

SPT Data				Estimated Parameters		
Borehole ID	DEPTH (m)	USCS	N_m	V_s	c_u (kPa)	ϕ (degree)
BSK-25	7.50-7.95	CL	28	252	168	-
	9.50-9.95		55	310	330	-
	10.50-10.95		32	263	192	-
	12.00-12.45	CH	54	309	324	-
	13.50-13.95		75	342	450	-
	15.00-15.45		R	-	-	-
	16.50-16.95		R	-	-	-
	18.00-18.45		R	-	-	-
	19.50-19.95		R	-	-	-
BSK-26	1.50-1.95	CL	12	194	72	-
	3.50-3.95		15	208	90	-
	4.50-4.95		30	257	180	-
	6.50-6.95		38	277	228	-
	7.50-7.95		45	292	270	-
	9.00-9.45	CH	76	343	456	-
	10.50-10.95		81	350	486	-
	12.00-12.45		82	351	492	-
	13.50-13.95		R	-	-	-
	15.00-15.45		R	-	-	-
	16.50-16.95		R	-	-	-
	18.00-18.45		R	-	-	-
	19.50-19.95		R	-	-	-
BSK-28	2.00-2.45	SC-SM	10	183	60	-
	3.00-3.45		18	220	108	-
	4.50-4.95		16	212	96	-
	6.50-6.95		11	189	66	-
	7.50-7.95	CL	27	249	162	-
	9.00-9.45		22	234	132	-
	10.50-10.95		56	312	336	-
	12.00-12.45		51	303	306	-

Table A.2: Estimated soil parameters by using SPT data (Cont'd).

SPT Data				Estimated Parameters		
Borehole ID	DEPTH (m)	USCS	N_m	V_s	c_u (kPa)	ϕ (degree)
BSK-28	13.50-13.95	CL	54	309	324	-
	15.00-15.45		49	300	294	-
	16.50-16.95		52	305	312	-
	18.00-18.45		58	316	348	-
	19.50-19.95		73	339	438	-
BSK-29	1.50-1.95	CL	14	203	84	-
	3.00-3.45		19	224	114	-
	5.00-5.45		24	240	144	-
	6.00-6.45		24	240	144	-
	8.00-8.45		36	272	216	-
	9.00-9.45	CH	34	268	204	-
	10.50-10.95		37	275	222	-
	12.00-12.45		42	286	252	-
	13.50-13.95		81	350	486	-
	15.00-15.45		R	-	-	-
	16.50-16.95		R	-	-	-
	18.00-18.45		R	-	-	-
	19.50-19.95		R	-	-	-
BSK-30	2.00-2.45	CH	16	212	96	-
	3.00-3.45		22	234	132	-
	4.50-4.95		26	246	156	-
	6.50-6.95		34	268	204	-
	7.50-7.95		32	263	192	-
	9.00-9.45		34	268	204	-
	11.00-11.45		54	309	324	-
	12.00-12.45		53	307	318	-
	13.50-13.95		62	322	372	-
	15.00-15.45		R	-	-	-
	16.50-16.95		R	-	-	-
	18.00-18.45		R	-	-	-
	19.50-19.95		R	-	-	-

SPT Data				Estimated Parameters		
Borehole ID	DEPTH (m)	USCS	N_m	V_s	c_u (kPa)	ϕ (degree)
BSK-31	1.50-1.95	CH	13	199	78	-
	3.50-3.95		22	234	132	-
	4.50-4.95		23	237	138	-
	6.50-6.95		26	246	156	-
	7.50-7.95		27	249	162	-
	9.00-9.45		31	260	186	-
	10.50-10.95	CL	27	249	162	-
	12.50-12.95		45	292	270	-
	13.50-13.95		70	334	420	-
	15.00-15.45		75	342	450	-
	16.50-16.95		R	-	-	-
	18.00-18.45		R	-	-	-
	19.50-19.95		R	-	-	-
BSK-32	1.50-1.95	CL	9	177	54	-
	3.50-3.95		16	212	96	-
	4.50-4.95		24	240	144	-
	6.50-6.95		24	240	144	-
	7.50-7.95		27	249	162	-
	9.00-9.45		32	263	192	-
	10.50-10.95		34	268	204	-
	12.00-12.45		37	275	222	-
	13.50-13.95		40	281	240	-
	15.00-15.45	CH	59	317	354	-
	16.50-16.95		R	-	-	-
	18.00-18.45		R	-	-	-
	19.50-19.95		R	-	-	-
CSK-1	1.50-1.95	CL	12	194	72	-
	3.50-3.95		18	220	108	-
	4.50-4.95		15	208	90	-
	6.00-6.45		18	220	108	-

Table A.2: Estimated soil parameters by using SPT data (Cont'd).

SPT Data				Estimated Parameters		
Borehole ID	DEPTH (m)	USCS	N_m	V_s	c_u (kPa)	ϕ (degree)
CSK-1	8.00-8.45	CL	39	279	234	-
	9.00-9.45		42	286	252	-
	10.50-10.95		42	286	252	-
	12.00-12.45	SM	43	288	258	-
	13.50-13.95	CL	59	317	354	-
	15.00-15.45		56	312	336	-
	16.50-16.95		65	327	390	-
	18.00-18.45		70	334	420	-
	19.50-19.95		R	-	-	-
	21.00-21.45		R	-	-	-
	24.00-24.45		R	-	-	-
	27.00-27.45		R	-	-	-
CSK-2	1.50-1.95		R	-	-	-
	3.50-3.95	CH	7	164	42	-
	4.50-4.95		11	189	66	-
	6.00-6.45		13	199	78	-
	7.50-7.95		6	157	36	-
	9.00-9.45		7	164	42	-
	10.50-10.95		5	148	30	-
	12.00-12.45		6	157	36	-
	13.50-13.95		6	157	36	-
	15.00-15.45		6	157	36	-
	16.50-16.95		3	126	18	-
	18.00-18.45		5	148	30	-
	19.50-19.95		4	138	24	-
	21.00-21.45		3	126	18	-
	24.00-24.45		4	138	24	-
	27.00-27.45		5	148	30	-
	30.00-30.45		9	177	54	-
	33.00-33.45		11	189	66	-
CSK-2	36.00-36.45	CH	R	-	-	-
	39.00-39.45		R	-	-	-
CSK-3	1.50-1.95	CL	5	148	30	-
	3.50-3.95		7	164	42	-
	4.50-4.95	SM	5	148	30	-
	6.00-6.45	CH	9	177	54	-
	7.50-7.95		3	126	18	-
	9.00-9.45		7	164	42	-
	10.50-10.95		5	148	30	-
	12.00-12.45		6	157	36	-
	13.50-13.95	CL	8	171	48	-
	15.00-15.45		7	164	42	-
	16.50-16.95		7	164	42	-
	18.00-18.45		6	157	36	-
	19.50-19.95	CH	5	148	30	-
	21.00-21.45		6	157	36	-
	24.00-24.45		4	138	24	-
	27.00-27.45		29	255	174	-
	30.00-30.45		35	270	210	-
	33.00-33.45		R	-	-	-
CSK-4	1.50-1.95		16	212	96	-
	3.50-3.95	SM	42	286	252	-
	4.50-4.95	CL	28	252	168	-
	6.00-6.45		19	224	114	-
	7.50-7.95		16	212	96	-
	9.00-9.45		17	216	102	-
	10.50-10.95		11	189	66	-
	12.00-12.45	SC	26	246	156	-
	13.50-13.95	CL	18	220	108	-
	15.00-15.45		12	194	72	-

Table A.2: Estimated soil parameters by using SPT data (Cont'd).

SPT Data				Estimated Parameters		
Borehole ID	DEPTH (m)	USCS	N_m	V_s	c_u (kPa)	ϕ (degree)
CSK-4	16.50-16.95	CH	10	183	60	-
	18.00-18.45		9	177	54	-
	19.50-19.95		17	216	102	-
	21.00-21.45		20	227	120	-
	24.00-24.45		23	237	138	-
	27.00-27.45		28	252	168	-
	30.00-30.45		35	270	210	-
	33.00-33.45		40	281	240	-
	36.00-36.45		46	294	276	-
	39.00-39.45		79	347	474	-
CSK-5	1.50-1.95	CL	10	183	60	-
	3.50-3.95		5	148	30	-
	4.50-4.95		14	203	84	-
	6.00-6.45		11	189	66	-
	7.50-7.95		5	148	30	-
	9.00-9.45		4	138	24	-
	10.50-10.95		4	138	24	-
	12.50-12.95		3	126	18	-
	13.50-13.95		2	111	12	-
	15.00-15.45	CH	4	138	24	-
	17.00-17.45		3	126	18	-
	18.00-18.45		5	148	30	-
	19.50-19.95		5	148	30	-
	21.50-21.95		4	138	24	-
	24.00-24.45		5	148	30	-
	27.00-27.45		6	157	36	-
	30.00-30.45		12	194	72	-
	33.00-33.45		22	234	132	-
	36.00-36.45		R	-	-	-
	39.00-39.45		R	-	-	-
	42.00-42.45		77	344	462	-

SPT Data				Estimated Parameters		
Borehole ID	DEPTH (m)	USCS	N_m	V_s	c_u (kPa)	ϕ (degree)
CSK-6	1.50-1.95	CH	R	-	-	-
	3.00-.3.45		9	177	54	-
	4.50-4.95		11	189	66	-
	6.00-6.45		11	189	66	-
	7.50-7.95		22	234	132	-
	9.00-9.45		27	249	162	-
	10.50-10.95		30	257	180	-
	12.00-12.45		30	257	180	-
	13.50-13.95		33	265	198	-
	15.00-15.45		26	246	156	-
	16.50-16.95		38	277	228	-
	18.00-18.45		39	279	234	-
	19.50-19.95		32	263	192	-
	21.00-21.45		44	290	264	-
	24.00-24.45		59	317	354	-
	27.00-27.45		70	334	420	-
CSK-7	1.50-1.95	CL	20	227	120	-
	3.50-3.95		19	224	114	-
	4.50-4.95		19	224	114	-
	6.50-6.95	CH	8	171	48	-
	7.50-7.95		17	216	102	-
	9.00-9.45		15	208	90	-
	10.50-10.95		18	220	108	-
	12.00-12.45		10	183	60	-
	13.50-13.95	SC	8	171	48	-
	15.00-15.45	CH	12	194	72	-
	16.50-16.95		9	177	54	-
	18.00-18.45		8	171	48	-
	19.50-19.95		7	164	42	-
	21.00-21.45		7	164	42	-

Table A.2: Estimated soil parameters by using SPT data (Cont'd).

SPT Data				Estimated Parameters		
Borehole ID	DEPTH (m)	USCS	N_m	V_s	c_u (kPa)	ϕ (degree)
CSK-7	24.00-24.45	SM	15	208	90	-
	27.00-27.45	CH	6	157	36	-
	30.00-30.45		15	208	90	-
	33.00-33.45		27	249	162	-
	36.00-36.45		R	-	-	-
	39.00-39.45		R	-	-	-
CSK-8	1.50-1.95	CL	12	194	72	-
	3.50-3.95		18	220	108	-
	4.50-4.95		16	212	96	-
	6.00-6.45	SC	18	220	108	-
	8.00-8.45	CH	17	216	102	-
	9.00-9.45		20	227	120	-
	10.50-10.95		19	224	114	-
	12.00-12.45		14	203	84	-
	13.50-13.95	CL	8	171	48	-
	15.00-15.45		8	171	48	-
	16.50-16.95		10	183	60	-
	18.00-18.45		13	199	78	-
	19.50-19.95		8	171	48	-
	21.00-21.45		10	183	60	-
	24.00-24.45	CH	32	263	192	-
	27.00-27.45		41	284	246	-
	30.00-30.45		29	255	174	-
	33.00-33.45		32	263	192	-
	36.00-36.45		65	327	390	-
CSK-9	1.50-1.95		R	-	-	-
	3.50-3.95	CH	22	234	132	-
	4.50-4.95		20	227	120	-
	6.00-6.45	CL	24	240	144	-
	7.50-7.95		29	255	174	-
CSK-9	9.50-9.95	CL	37	275	222	-
	10.50-10.95	CH	33	265	198	-
	12.00-12.45	CL	39	279	234	-
	13.50-13.95		42	286	252	-
	15.00-15.45		36	272	216	-
	16.50-16.95		40	281	240	-
	18.00-18.45	CH	43	288	258	-
	19.50-19.95		48	298	288	-
	21.00-21.45		51	303	306	-
	24.00-24.45		82	351	492	-
	27.00-27.45		R	-	-	-
CSK-10	1.50-1.95	CL	5	148	30	-
	3.50-3.95		46	294	276	-
	4.50-4.95	GM	44	290	264	-
	6.00-6.45	CL	10	183	60	-
	7.50-7.95		12	194	72	-
	9.50-9.95		10	183	60	-
	10.50-10.95		9	177	54	-
	12.00-12.45		12	194	72	-
	13.50-13.95		10	183	60	-
	15.00-15.45		20	227	120	-
	16.50-16.95		20	227	120	-
	18.00-18.45		5	148	30	-
	19.50-19.95		6	157	36	-
	21.00-21.45		27	249	162	-
	24.00-24.45		31	260	186	-
	27.00-27.45	CH	R	-	-	-
CSK-11	1.50-1.95	CL	14	203	84	-
	3.50-3.95		13	199	78	-
	4.50-4.95		18	220	108	-

Table A.2: Estimated soil parameters by using SPT data (Cont'd).

SPT Data				Estimated Parameters		
Borehole ID	DEPTH (m)	USCS	N_m	V_s	c_u (kPa)	ϕ (degree)
CSK-11	6.50-6.95	CL	27	249	162	-
	7.50-7.95	SM	43	288	258	-
	9.00-9.45	CL	38	277	228	-
	10.50-10.95		15	208	90	-
	12.00-12.45		10	183	60	-
	13.50-13.95		12	194	72	-
	15.00-15.45		12	194	72	-
	16.50-16.95		13	199	78	-
	18.00-18.45		14	203	84	-
	19.50-19.95		14	203	84	-
	21.00-21.45		11	189	66	-
	24.00-24.45	SC	33	265	198	-
	27.00-27.45	CL	30	257	180	-
	30.00-30.45		35	270	210	-
	33.00-33.45		23	237	138	-
	36.00-36.45		47	296	282	-
	39.00-39.45	CH	79	347	474	-
CSK-12	1.50-1.95	CL	35	270	210	-
	3.50-3.95		32	263	192	-
	4.50-4.95		39	279	234	-
	6.50-6.95		27	249	162	-
	7.50-7.95		25	243	150	-
	9.00-9.45		29	255	174	-
	10.50-10.95		34	268	204	-
	12.00-12.45		35	270	210	-
	13.50-13.95	CH	31	260	186	-
	15.00-15.45		35	270	210	-
	16.50-16.95		19	224	114	-
	18.00-18.45	SM	45	292	270	-
	19.50-19.95	CH	51	303	306	-

SPT Data				Estimated Parameters		
Borehole ID	DEPTH (m)	USCS	N_m	V_s	c_u (kPa)	ϕ (degree)
CSK-12	21.00-21.45	CH	43	288	258	-
	24.00-24.45		R	-	-	-
	27.00-27.45		R	-	-	-
CSK-13	1.50-1.95	CL	R	-	-	-
	3.00-3.45		15	208	90	-
	4.50-4.95		11	189	66	-
	6.50-6.95		17	216	102	-
	7.50-7.95		10	183	60	-
	9.00-9.45		12	194	72	-
	10.50-10.95	SM	22	234	132	-
	12.00-12.45	SM	26	246	156	-
	13.50-13.95	CH	13	199	78	-
	15.00-15.45		15	208	90	-
	16.50-16.95		12	194	72	-
	18.00-18.45		11	189	66	-
	19.50-19.95		10	183	60	-
	21.00-21.45		11	189	66	-
	24.00-24.45		18	220	108	-
	27.00-27.45		18	220	108	-
	30.00-30.45		19	224	114	-
	33.00-33.45		28	252	168	-
	36.00-36.45		26	246	156	-
	39.00-39.45		36	272	216	-
CSK-14	1.50-1.95	CL	11	189	66	-
	3.50-3.95		12	194	72	-
	4.50-4.95		14	203	84	-
	6.00-6.45		12	194	72	-
	7.50-7.95	GM	48	298	288	-
	9.00-9.45	CL	8	171	48	-
	10.50-10.95		7	164	42	-

Table A.2: Estimated soil parameters by using SPT data (Cont'd).

SPT Data				Estimated Parameters		
Borehole ID	DEPTH (m)	USCS	N_m	V_s	c_u (kPa)	ϕ (degree)
CSK-14	12.00-12.45	SM	24	240	144	-
	13.50-13.95	CH	8	171	48	-
	15.00-15.45		10	183	60	-
	16.50-16.95		13	199	78	-
	18.00-18.45		12	194	72	-
	19.50-19.95		16	212	96	-
	21.00-21.45		22	234	132	-
	24.00-24.45		34	268	204	-
	27.00-27.45		29	255	174	-
CSK-15	1.50-1.95	CL	8	171	48	-
	3.50-3.95		12	194	72	-
	4.50-4.95		32	263	192	-
	6.00-6.45		15	208	90	-
	7.50-7.95		16	212	96	-
	9.00-9.45		22	234	132	-
	10.50-10.95		19	224	114	-
	12.00-12.45		26	246	156	-
	13.50-13.95		14	203	84	-
	15.00-15.45		15	208	90	-
	16.50-16.95		11	189	66	-
	18.00-18.45		13	199	78	-
	19.50-19.95		36	272	216	-
	21.00-21.45		13	199	78	-
	24.00-24.45		26	246	156	-
	27.00-27.45		32	263	192	-
CSK-16	1.50-1.95	CL	15	208	90	-
	3.50-3.95		14	203	84	-
	4.50-4.95		14	203	84	-
	6.00-6.45		17	216	102	-
	7.50-7.95		24	240	144	-

SPT Data				Estimated Parameters		
Borehole ID	DEPTH (m)	USCS	N_m	V_s	c_u (kPa)	ϕ (degree)
CSK-16	9.00-9.45	CL	25	243	150	-
	10.50-10.95		17	216	102	-
	12.50-12.95		21	231	126	-
	13.50-13.95	CH	26	246	156	-
	15.00-15.45		25	243	150	-
	16.50-16.95		27	249	162	-
	18.00-18.45		29	255	174	-
	19.50-19.95		24	240	144	-
	21.00-21.45		28	252	168	-
	24.00-24.45		32	263	192	-
	27.00-27.45	CL	55	310	330	-
	30.00-30.45		71	336	426	-
	33.00-33.45		33	265	198	-
CSK-17	1.50-1.95	CL	19	224	114	-
	3.00-3.45		32	263	192	-
	5.00-5.45		31	260	186	-
	6.00-6.45		38	277	228	-
	7.50-7.95		49	300	294	-
	9.50-9.95		71	336	426	-
	10.50-10.95		80	349	480	-
	12.00-12.45		76	343	456	-
	13.50-13.95		84	354	504	-
	15.00-15.45		41	284	246	-
	16.50-16.95		48	298	288	-
	18.00-18.45		48	298	288	-
	19.50-19.95		55	310	330	-
	21.00-21.45		46	294	276	-
	24.00-24.45		49	300	294	-
	27.00-27.45	CH	66	328	396	-

Table A.2: Estimated soil parameters by using SPT data (Cont'd).

SPT Data				Estimated Parameters		
Borehole ID	DEPTH (m)	USCS	N_m	V_s	c_u (kPa)	ϕ (degree)
CSK-18	1.50-1.95	CH	6	157	36	-
	3.50-3.95		8	171	48	-
	4.50-4.95		7	164	42	-
	6.00-6.45		10	183	60	-
	8.00-8.45		14	203	84	-
	9.00-9.45		12	194	72	-
	10.50-10.95	SM	26	246	156	-
	12.00-12.45	CH	12	194	72	-
	13.50-13.95		14	203	84	-
	15.00-15.45	SC	20	227	120	-
	16.50-16.95	CH	24	240	144	-
	18.00-18.45		20	227	120	-
	19.50-19.95		22	234	132	-
	21.00-21.45		25	243	150	-
	24.00-24.45		17	216	102	-
	27.00-27.45		24	240	144	-
	30.00-30.45		51	303	306	-
	33.00-33.45		70	334	420	-
	36.00-36.45		R	-	-	-
	39.00-39.45		R	-	-	-
CSK-19	1.50-1.95	SM	15	208	90	-
	3.50-3.95		38	277	228	-
	4.50-4.95		43	288	258	-
	6.00-6.45		47	296	282	-
	7.50-7.95	CH	15	208	90	-
	9.00-9.45		16	212	96	-
	10.50-10.95		20	227	120	-
	12.00-12.45		27	249	162	-
	13.50-13.95		29	255	174	-
	15.00-15.45		33	265	198	-
CSK-19	16.50-16.95	CH	36	272	216	-
	18.00-18.45		40	281	240	-
	19.50-19.95		32	263	192	-
	21.00-21.45		36	272	216	-
	24.00-24.45		38	277	228	-
	27.00-27.45		48	298	288	-
CSK-20	1.50-1.95	CL	7	164	42	-
	3.50-3.95		9	177	54	-
	4.50-4.95		8	171	48	-
	6.50-6.95		13	199	78	-
	7.50-7.95	SM	16	212	96	-
	9.00-9.45	CL	13	199	78	-
	10.50-10.95		19	224	114	-
	12.00-12.45		21	231	126	-
	13.50-13.95		30	257	180	-
	15.00-15.45		30	257	180	-
	16.50-16.95	SC	36	272	216	-
	18.00-18.45	CL	16	212	96	-
	19.50-19.95		12	194	72	-
	21.00-21.45		9	177	54	-
	24.00-24.45		13	199	78	-
	27.00-27.45		26	246	156	-
	30.00-30.45		45	292	270	-
DSK-13	1.50-1.95	CH	11	189	66	-
	3.50-3.95		11	189	66	-
	4.50-4.95		14	203	84	-
	6.50-6.95		17	216	102	-
	7.50-7.95		18	220	108	-
	9.00-9.45		30	257	180	-
	10.50-10.95		31	260	186	-

Table A.2: Estimated soil parameters by using SPT data (Cont'd).

SPT Data				Estimated Parameters		
Borehole ID	DEPTH (m)	USCS	N_m	V_s	c_u (kPa)	ϕ (degree)
DSK-13	12.00-12.45	CH	R	-	-	-
	13.50-13.95		R	-	-	-
	15.00-15.45		R	-	-	-
	16.50-16.95		R	-	-	-
	18.00-18.45		R	-	-	-
	19.50-19.95		R	-	-	-
DSK-18	1.50-1.95	CH	6	157	36	-
	3.00-3.45		7	164	42	-
	4.50-4.95		11	189	66	-
	6.00-6.45		21	231	126	-
	7.50-7.95		24	240	144	-
	9.00-9.45		29	255	174	-
	10.50-10.95		R	-	-	-
	12.00-12.45		R	-	-	-
	13.50-13.95		R	-	-	-
	15.00-15.45		R	-	-	-
	16.50-16.95		R	-	-	-
	18.00-18.45		R	-	-	-
	19.50-19.95		R	-	-	-
DSK-19	1.50-1.95	CL	13	199	78	-
	3.50-3.95		7	164	42	-
	4.50-4.95		16	212	96	-
	6.50-6.95	CH	20	227	120	-
	7.50-7.95		22	234	132	-
	9.00-9.45		22	234	132	-
	11.00-11.45		25	243	150	-
	12.00-12.45		35	270	210	-
	13.50-13.95		28	252	168	-
	15.00-15.45	SC	30	257	180	-
	16.50-16.95	CH	29	255	174	-

SPT Data				Estimated Parameters		
Borehole ID	DEPTH (m)	USCS	N_m	V_s	c_u (kPa)	ϕ (degree)
DSK-19	18.00-18.45	CH	34	268	204	-
	19.50-19.95		33	265	198	-
DSK-23	1.50-1.95	CH	10	183	60	-
	3.50-3.95		14	203	84	-
	4.50-4.95		15	208	90	-
	6.50-6.95		16	212	96	-
	7.50-7.95		20	227	120	-
	9.00-9.45		29	255	174	-
	10.50-10.95		36	272	216	-
	12.00-12.45		62	322	372	-
	13.50-13.95		R	-	-	-
	15.00-15.45		R	-	-	-
	16.50-16.95		R	-	-	-
	18.00-18.45		R	-	-	-
	19.50-19.95		R	-	-	-
DSK-24	1.50-1.95	CL	10	183	60	-
	3.50-3.95		15	208	90	-
	4.50-4.95		16	212	96	-
	6.50-6.95		20	227	120	-
	7.50-7.95		23	237	138	-
	9.00-9.45		26	246	156	-
	11.00-11.45	CH	32	263	192	-
	12.00-12.45		47	296	282	-
	13.50-13.95		50	301	300	-
	15.00-15.45		59	317	354	-
	16.50-16.95		71	336	426	-
	18.00-18.45		R	-	-	-
	19.50-19.95		R	-	-	-
DSK-26	1.50-1.95	CL	8	171	48	-
	3.50-3.95		12	194	72	-

Table A.2: Estimated soil parameters by using SPT data (Cont'd).

SPT Data				Estimated Parameters		
Borehole ID	DEPTH (m)	USCS	N_m	V_s	c_u (kPa)	ϕ (degree)
DSK-26	4.50-4.95	CL	13	199	78	-
	6.00-6.45		22	234	132	-
	8.00-8.45		38	277	228	-
	9.00-9.45		38	277	228	-
	10.50-10.95		38	277	228	-
	12.00-12.45		58	316	348	-
	13.50-13.95		58	316	348	-
	15.00-15.45		60	319	360	-
	16.50-16.95		R	-	-	-
	18.00-18.45		R	-	-	-
	19.50-19.95		R	-	-	-
DSK-30	1.50-1.95	CL	12	194	72	-
	3.00-3.45		11	189	66	-
	4.50-4.95		14	203	84	-
	6.00-6.45	CH	20	227	120	-
	7.50-7.95		29	255	174	-
	9.00-9.45		41	284	246	-
	10.50-10.95		R	-	-	-
	12.00-12.45		R	-	-	-
	13.50-13.95		R	-	-	-
	15.00-15.45		R	-	-	-
	16.50-16.95		R	-	-	-
	18.00-18.45		R	-	-	-
DSK-31	1.50-1.95	CH	11	189	66	-
	3.50-3.95		12	194	72	-
	4.50-4.95		15	208	90	-
	6.50-6.95		17	216	102	-
	7.50-7.95		19	224	114	-
	9.00-9.45		26	246	156	-
	11.00-11.45		51	303	306	-
DSK-31	12.00-12.45	CH	62	322	372	-
	13.50-13.95		R	-	-	-
	15.00-15.45		R	-	-	-
	16.50-16.95		R	-	-	-
	18.00-18.45		R	-	-	-
	19.50-19.95		R	-	-	-
DSK-32	1.50-1.95	CH	14	203	84	-
	3.50-3.95		15	208	90	-
	4.50-4.95		22	234	132	-
	6.50-6.95		24	240	144	-
	7.50-7.95		30	257	180	-
	9.00-9.45		33	265	198	-
	11.00-11.45		48	298	288	-
	12.00-12.45		R	-	-	-
	13.50-13.95		44	290	264	-
	15.00-15.45		47	296	282	-
	16.50-16.95	CL	48	298	288	-
	18.00-18.45		53	307	318	-
	19.50-19.95		R	-	-	-
DSK-33	1.50-1.95	CL	28	252	168	-
	3.00-3.45		18	220	108	-
	4.50-4.95		20	227	120	-
	6.00-6.45		17	216	102	-
	7.50-7.95	CH	R	-	-	-
	9.00-9.45		R	-	-	-
	10.50-10.95		R	-	-	-
	12.00-12.45		R	-	-	-
	13.50-13.95		R	-	-	-
	15.00-15.45		R	-	-	-

Table A.2: Estimated soil parameters by using SPT data (Cont'd).

SPT Data				Estimated Parameters		
Borehole ID	DEPTH (m)	USCS	N_m	V_s	c_u (kPa)	ϕ (degree)
DSK-34	1.50-1.95	CL	9	177	54	-
	3.00-3.45		15	208	90	-
	4.50-4.95		23	237	138	-
	6.00-6.45		23	237	138	-
	7.50-7.95		33	265	198	-
	9.00-9.45		28	252	168	-
	10.50-10.95		26	246	156	-
	12.00-12.45		39	279	234	-
	13.50-13.95		R	-	-	-
	15.00-15.45		45	292	270	-
	16.50-16.95		49	300	294	-
	18.00-18.45		R	-	-	-
	19.50-19.95		59	317	354	-
DSK-35	1.50-1.95	CL	25	243	150	-
	3.00-3.45		21	231	126	-
	5.00-5.45		21	231	126	-
	6.00-6.45	SM	28	252	168	-
	7.50-7.95		30	257	180	-
	9.00-9.45	CL	24	240	144	-
	10.50-10.95	SM	22	234	132	-
	12.00-12.45	CL	24	240	144	-
	13.50-13.95		28	252	168	-
	15.00-15.45		37	275	222	-
	16.50-16.95	SM	32	263	192	-
	18.00-18.45	CL	28	252	168	-
	19.50-19.95		40	281	240	-
DSK-38	1.50-1.95	CH	17	216	102	-
	3.50-3.95		10	183	60	-
	4.50-4.95		14	203	84	-
	6.50-6.95		22	234	132	-

SPT Data				Estimated Parameters		
Borehole ID	DEPTH (m)	USCS	N_m	V_s	c_u (kPa)	ϕ (degree)
DSK-38	7.50-7.95	CH	25	243	150	-
	9.00-9.45		19	224	114	-
	11.00-11.45		44	290	264	-
	12.00-12.45		26	246	156	-
	13.50-13.95		47	296	282	-
	15.00-15.45		R	-	-	-
	16.50-16.95		34	268	204	-
	18.00-18.45		38	277	228	-
	19.50-19.95		R	-	-	-
DSK-39	1.50-1.95	CL	8	171	48	-
	3.50-3.95		14	203	84	-
	4.50-4.95		20	227	120	-
	6.00-6.45		22	234	132	-
	8.00-8.45		21	231	126	-
	9.00-9.45		24	240	144	-
	10.50-10.95		29	255	174	-
	12.00-12.45		32	263	192	-
	13.50-13.95		40	281	240	-
	15.00-15.45		45	292	270	-
	16.50-16.95		55	310	330	-
	18.00-18.45		47	296	282	-
	19.50-19.95	SC	52	305	312	-
DSK-40	1.50-1.95	CL	7	164	42	-
	3.00-3.45	SM	9	177	54	-
	4.50-4.95	CL	13	199	78	-
	6.00-6.45		19	224	114	-
	7.50-7.95		26	246	156	-
	9.00-9.45	SM	31	260	186	-
	10.50-10.95	CL	38	277	228	-
	12.00-12.45		48	298	288	-

Table A.2: Estimated soil parameters by using SPT data (Cont'd).

SPT Data				Estimated Parameters		
Borehole ID	DEPTH (m)	USCS	N_m	V_s	c_u (kPa)	ϕ (degree)
DSK-40	13.50-13.95	CL	55	310	330	-
	15.00-15.45		70	334	420	-
	16.50-16.95		87	358	522	-
	18.00-18.45		R	-	-	-
	19.50-19.95		R	-	-	-
DSK-41	1.50-1.95	CL	9	177	54	-
	3.50-3.95		14	203	84	-
	4.50-4.95		16	212	96	-
	6.00-6.45	CH	14	203	84	-
	8.00-8.45		17	216	102	-
	9.00-9.45		23	237	138	-
	10.50-10.95		27	249	162	-
	12.50-12.95		28	252	168	-
	13.50-13.95		31	260	186	-
	15.00-15.45		28	252	168	-
	16.50-16.95		28	252	168	-
	18.00-18.45		72	337	432	-
	19.50-19.95		73	339	438	-
DSK-44	1.50-1.95	CH	10	183	60	-
	3.50-3.95		13	199	78	-
	4.50-4.95		15	208	90	-
	6.50-6.95		17	216	102	-
	7.50-7.95		18	220	108	-
	9.00-9.45		20	227	120	-
	11.00-11.45		21	231	126	-
	12.00-12.45		25	243	150	-
	13.50-13.95		57	314	342	-
	15.00-15.45		63	324	378	-
	16.50-16.95		56	312	336	-
	18.00-18.45		R	-	-	-
	19.50-19.95		R	-	-	-

SPT Data				Estimated Parameters		
Borehole ID	DEPTH (m)	USCS	N_m	V_s	c_u (kPa)	ϕ (degree)
DSK-45	1.50-1.95	CL	11	189	66	-
	3.50-3.95		14	203	84	-
	4.50-4.95		14	203	84	-
	6.50-6.95		34	268	204	-
	7.50-7.95		12	194	72	-
	9.00-9.45	CH	15	208	90	-
	10.50-10.95		23	237	138	-
	12.00-12.45		44	290	264	-
	13.50-13.95		41	284	246	-
	15.00-15.45		43	288	258	-
	16.50-16.95		47	296	282	-
	18.00-18.45		55	310	330	-
	19.50-19.95		67	330	402	-
DSK-46	1.50-1.95	CL	10	183	60	-
	3.00-3.45		17	216	102	-
	4.50-4.95		21	231	126	-
	6.00-6.45		28	252	168	-
	7.50-7.95		21	231	126	-
	9.00-9.45		28	252	168	-
	10.50-10.95		37	275	222	-
	12.00-12.45		33	265	198	-
	13.50-13.95		38	277	228	-
	15.00-15.45		R	-	-	-
	16.50-16.95	SM	55	310	330	-
	18.00-18.45	CH	54	309	324	-
	19.50-19.95		51	303	306	-
DSK-47	1.50-1.95	CL	8	171	48	-
	3.50-3.95		18	220	108	-
	4.50-4.95		25	243	150	-
	6.00-6.45	SM	25	243	150	-

Table A.2: Estimated soil parameters by using SPT data (Cont'd).

SPT Data				Estimated Parameters		
Borehole ID	DEPTH (m)	USCS	N_m	V_s	c_u (kPa)	ϕ (degree)
DSK-47	8.00-8.45	CH	35	270	210	-
	9.00-9.45		47	296	282	-
	10.50-10.95		57	314	342	-
	12.00-12.45		52	305	312	-
	13.50-13.95		60	319	360	-
	15.00-15.45		64	325	384	-
	16.50-16.95		64	325	384	-
	18.00-18.45		79	347	474	-
	19.50-19.95		90	361	540	-
DSK-50	1.50-1.95	CH	12	194	72	-
	3.00-3.45		14	203	84	-
	4.50-4.95		20	227	120	-
	6.50-6.95		37	275	222	-
	7.50-7.95		R	-	-	-
	9.00-9.45		R	-	-	-
	10.50-10.95		R	-	-	-
	12.00-12.45		R	-	-	-
	13.50-13.95		R	-	-	-
	15.00-15.45		R	-	-	-
DSK-51	1.50-1.95	CL	18	220	108	-
	3.50-3.95	SM	25	243	150	-
	4.50-4.95	CL	23	237	138	-
	6.00-6.45	SM	22	234	132	-
	7.50-7.95	CL	15	208	90	-
	9.00-9.45		19	224	114	-
	10.50-10.95		28	252	168	-
	12.00-12.45		25	243	150	-
	13.50-13.95		16	212	96	-
	15.00-15.45		26	246	156	-
	16.50-16.95		33	265	198	-

SPT Data				Estimated Parameters		
Borehole ID	DEPTH (m)	USCS	N_m	V_s	c_u (kPa)	ϕ (degree)
DSK-51	18.00-18.45	CL	30	257	180	-
	19.50-19.95	SM	37	275	222	-
DSK-54	1.50-1.95	CL	9	177	54	-
	3.00-3.45		6	157	36	-
	4.50-4.95		11	189	66	-
	6.00-6.45		23	237	138	-
	7.50-7.95		31	260	186	-
	9.00-9.45		41	284	246	-
	10.50-10.95		R	-	-	-
	12.00-12.45		R	-	-	-
	13.50-13.95		R	-	-	-
	15.00-15.45		R	-	-	-
	16.50-16.95		R	-	-	-
	18.00-18.45		R	-	-	-
DSK-55	1.50-1.95	CH	9	177	54	-
	3.50-3.95		13	199	78	-
	4.50-4.95		13	199	78	-
	6.50-6.95		17	216	102	-
	7.50-7.95		20	227	120	-
	9.00-9.45		27	249	162	-
	11.00-11.45		32	263	192	-
	12.00-12.45		47	296	282	-
	13.50-13.95		54	309	324	-
	15.00-15.45		R	-	-	-
	16.50-16.95		R	-	-	-
	18.00-18.45		R	-	-	-
	19.50-19.95		R	-	-	-
DSK-56	1.50-1.95	CH	13	199	78	-
	3.50-3.95		15	208	90	-
	4.50-4.95		18	220	108	-

Table A.2: Estimated soil parameters by using SPT data (Cont'd).

SPT Data				Estimated Parameters		
Borehole ID	DEPTH (m)	USCS	N_m	V_s	c_u (kPa)	ϕ (degree)
DSK-56	6.50-6.95	CH	20	227	120	-
	7.50-7.95		22	234	132	-
	9.00-9.45		23	237	138	-
	11.00-11.45		30	257	180	-
	12.00-12.45		R	-	-	-
	13.50-13.95		R	-	-	-
	15.00-15.45		R	-	-	-
	16.50-16.95		R	-	-	-
	18.00-18.45		R	-	-	-
	19.50-19.95		R	-	-	-
DSK-57	1.50-1.95	CH	9	177	54	-
	3.50-3.95		15	208	90	-
	4.50-4.95		24	240	144	-
	6.50-6.95		32	263	192	-
	7.50-7.95		34	268	204	-
	9.00-9.45		44	290	264	-
	11.00-11.45		54	309	324	-
	12.00-12.45		R	-	-	-
	13.50-13.95		R	-	-	-
	15.00-15.45		R	-	-	-
	16.50-16.95		R	-	-	-
	18.00-18.45		R	-	-	-
	19.50-19.95		R	-	-	-
DSK-58	1.50-1.95	CH	38	277	228	-
	3.50-3.95		22	234	132	-
	4.50-4.95		28	252	168	-
	6.00-6.45		20	227	120	-
	8.00-8.45		23	237	138	-
	9.00-9.45		20	227	120	-
	10.50-10.95		24	240	144	-
DSK-58	12.50-12.95	CH	44	290	264	-
	13.50-13.95		26	246	156	-
	15.00-15.45		37	275	222	-
	16.50-16.95		R	-	-	-
	18.00-18.45		R	-	-	-
	19.50-19.95		R	-	-	-
DSK-62	1.50-1.95	CL	14	203	84	-
	3.00-3.45		20	227	120	-
	4.50-4.95	SM	21	231	126	-
	6.00-6.45	CL	14	203	84	-
	7.50-7.95	SC	13	199	78	-
	9.00-9.45	CH	20	227	120	-
	10.50-10.95		27	249	162	-
	12.00-12.45		28	252	168	-
	13.50-13.95		27	249	162	-
	15.00-15.45		28	252	168	-
	16.50-16.95		33	265	198	-
	18.00-18.45		18	220	108	-
	19.50-19.95		36	272	216	-
DSK-63	1.50-1.95	CH	8	171	48	-
	3.00-3.45		12	194	72	-
	4.50-4.95	CL	14	203	84	-
	6.00-6.45		35	270	210	-
	7.50-7.95		53	307	318	-
	9.00-9.45		R	-	-	-
	10.50-10.95		R	-	-	-
	12.00-12.45		R	-	-	-
	13.50-13.95		R	-	-	-
	15.00-15.45		R	-	-	-
	16.50-16.95		R	-	-	-

Table A.2: Estimated soil parameters by using SPT data (Cont'd).

SPT Data				Estimated Parameters		
Borehole ID	DEPTH (m)	USCS	N_m	V_s	c_u (kPa)	ϕ (degree)
DSK-64	1.50-1.95	CH	17	216	102	-
	3.00-3.45		14	203	84	-
	4.50-4.95		20	227	120	-
	6.00-6.45		32	263	192	-
	7.50-7.95		29	255	174	-
	9.00-9.45		38	277	228	-
	10.50-10.95		R	-	-	-
	12.00-12.45		R	-	-	-
	13.50-13.95		R	-	-	-
	15.00-15.45		R	-	-	-
	16.50-16.95		R	-	-	-
	18.00-18.45		R	-	-	-
DSK-65	1.50-1.95	CH	17	216	102	-
	3.50-3.95		15	208	90	-
	4.50-4.95		24	240	144	-
	6.00-6.45		26	246	156	-
	8.00-8.45		59	317	354	-
	9.00-9.45		R	-	-	-
	10.50-10.95		R	-	-	-
	12.00-12.45		R	-	-	-
	13.50-13.95		R	-	-	-
	15.00-15.45		R	-	-	-
	16.50-16.95		R	-	-	-
	18.00-18.45		R	-	-	-
	19.50-19.95		R	-	-	-
DSK-66	1.50-1.95	CL	21	231	126	-
	3.00-3.45		22	234	132	-
	5.00-5.45	CH	29	255	174	-
	6.00-6.45		31	260	186	-
	8.00-8.45		38	277	228	-

SPT Data				Estimated Parameters		
Borehole ID	DEPTH (m)	USCS	N_m	V_s	c_u (kPa)	ϕ (degree)
DSK-66	9.00-9.45	CH	42	286	252	-
	11.00-11.45		54	309	324	-
	12.00-12.45		57	314	342	-
	13.50-13.95		63	324	378	-
	15.00-15.45		R	-	-	-
	16.50-16.95		R	-	-	-
	18.00-18.45		R	-	-	-
	19.50-19.95		R	-	-	-
DSK-70	1.50-1.95	CL	18	220	108	-
	3.00-3.45		21	231	126	-
	4.50-4.95		28	252	168	-
	6.00-6.45		26	246	156	-
	7.50-7.95		42	286	252	-
	9.00-9.45	CH	41	284	246	-
	10.50-10.95		R	-	-	-
	12.00-12.45		R	-	-	-
	13.50-13.95		R	-	-	-
	15.00-15.45		R	-	-	-
	16.50-16.95		R	-	-	-
	18.00-18.45		R	-	-	-
DSK-71	1.50-1.95	CL	12	194	72	-
	3.50-3.95		12	194	72	-
	4.50-4.95		16	212	96	-
	6.50-6.95		16	212	96	-
	7.50-7.95		21	231	126	-
	9.00-9.45		20	227	120	-
	11.00-11.45		R	-	-	-
	12.00-12.45		R	-	-	-
	13.50-13.95		R	-	-	-
	15.00-15.45		52	305	312	-

Table A.2: Estimated soil parameters by using SPT data (Cont'd).

SPT Data				Estimated Parameters		
Borehole ID	DEPTH (m)	USCS	N_m	V_s	c_u (kPa)	ϕ (degree)
DSK-71	16.50-16.95	CL	55	310	330	-
	18.00-18.45		R	-	-	-
	19.50-19.95		R	-	-	-
DSK-72	1.50-1.95	CL	24	240	144	-
	3.00-3.45		27	249	162	-
	5.00-5.45		26	246	156	-
	6.00-6.45		24	240	144	-
	7.50-7.95		32	263	192	-
	9.50-9.95		24	240	144	-
	10.50-10.95		31	260	186	-
	12.00-12.45		33	265	198	-
	14.00-14.45		37	275	222	-
	15.00-15.45	CH	57	314	342	-
	16.50-16.95		40	281	240	-
	18.00-18.45		43	288	258	-
	19.50-19.95		66	328	396	-
DSK-75	1.50-1.95	CH	10	183	60	-
	3.00-3.45	GM	24	240	144	-
	4.50-4.95	CH	18	220	108	-
	6.00-6.45		28	252	168	-
	7.50-7.95		29	255	174	-
	9.00-9.45		R	-	-	-
	10.50-10.95		R	-	-	-
	12.00-12.45		R	-	-	-
	13.50-13.95		R	-	-	-
	15.00-15.45		R	-	-	-
	16.50-16.95		R	-	-	-
DSK-76	1.50-1.95	CH	10	183	60	-
	3.00-3.45		16	212	96	-
	4.50-4.95		25	243	150	-

SPT Data				Estimated Parameters		
Borehole ID	DEPTH (m)	USCS	N_m	V_s	c_u (kPa)	ϕ (degree)
DSK-76	6.00-6.45	CH	34	268	204	-
	7.50-7.95		36	272	216	-
	9.00-9.45		45	292	270	-
	10.50-10.95		30	257	180	-
	12.00-12.45		49	300	294	-
	13.50-13.95		58	316	348	-
	15.00-15.45		R	-	-	-
	16.50-16.95		65	327	390	-
	18.00-18.45		R	-	-	-
	19.50-19.95		R	-	-	-

APPENDIX B

DISTRIBUTION OF BUILDING DAMAGE MAP AND TABULAR DAMAGE DATA FOR THE STREETS

Table B.1: Bahçelievler quarter - spatial distribution of damage table with respect to streets.

Street Name	Number of Building	Number of Collapsed Building
Aldoğan	7	1
Altıncan	6	0
Asude	3	0
Cemal Nadir	9	0
Çağlar	2	0
Çaldıran	7	0
Demirel	5	0
Deniz	7	0
Derya	3	0
Donanma	5	0
Eczacı	21	0
Eğitim	7	0
Ertuğrul Gazi	24	0
Evliya Çelebi	7	0
Gür	9	0
Gürsel	9	1
Gürses	10	0
Halide Edip Adıvar	13	1
Hasan Tahsin	7	0
Hüseyin Rahmi	4	0
İmar	25	0
Kültür	6	0
Marmara	24	4
Meriç	8	0
Mesire Yolu	16	0
Mithat Paşa	12	3
Muammer Aksoy	3	0
Namık Kemal	4	2

Street Name	Number of Building	Number of Collapsed Building
Nenehatun	10	3
Orhan Veli	12	0
Oruçreis	8	3
Öğrenci	8	0
Öğretmen	6	0
Öz Kartal	4	0
Pirireis	4	1
Plaj	12	0
Rauf Orbay	4	0
Sait Faik Abasıyanık	18	5
Spor	37	3
Stadyum	23	0
Ş.Çevik	5	0
Şebnem	5	0
Talat Paşa	13	1
Tarancı	13	0
Taş	11	2
Timurtaş	9	0
Türkmen	5	0
Ulubey	10	3
Yakupbey	6	0
Yavuz Sultan Selim	12	0
Yıldırım Beyazit	18	0
Zambak	20	3
Ziverbey	5	0
Ziya Paşa	8	0
Fatih	67	1
Gazipaşa	48	3
TOTAL	**664**	**40**

Table B.2: Rüstempaşa quarter - spatial distribution of damage table with respect to streets.

Street Name	Number of Building	Number of Collapsed Building
Değirmen	8	0
Cami	17	0
Harmanlar	18	0
Pınar	12	0
Çeşme	12	2
Huzur	20	0
Barış	6	0
Park	1	0
Bar	1	0
Hürriyet	27	0
Orta	18	0
Çardak	6	0
Çakıllı	13	2
Yaseri Asim	18	0
Öncü	2	0
Kaymakam Erkin	42	0
Kartal	35	1
Geziyolu	13	1
Kısa	2	0
Şair Nedim	14	0
Şefika	8	0
Şahin	10	1
Dere	14	0
Sema	2	0
İsmet Acar	48	0
Cumhuriyet	24	0
Gazipaşa	15	0
Fatih	18	0
Malazgirt	20	5
TOTAL	**444**	**12**

Table B.3: Kazım Karabekir quarter - spatial distribution of damage table with respect to streets.

Street Name	Number of Building	Number of Collapsed Building
Esin	8	0
Zeybek	29	0
Engin	9	0
Arzu	6	0
İpekçi	6	0
Kadırga	9	1
Kamberbaba	25	0
Doruk	7	0
Polat	2	0
Onur	18	2
Asude	7	7
Barut	13	8
Mehmet Akif	5	0
Ertürk	10	10
Kumru	8	1
Kervan	6	3
Gamze	5	3
Akyaka	29	15
Kaçkar	7	1
Ihlamur	9	2
Dik	10	0
Yonca	8	0
Nilüfer	2	0
Özdemir	6	0
Kavak	19	1
Yavuz	10	8
Gebeçınar	5	3
Depo	2	0
Aksoy	17	0
Örnek	1	0
Fulya	15	0
Ufuk	1	0
Utku	4	0
Çınar	1	0

Street Name	Number of Building	Number of Collapsed Building
Ağaç	4	0
Manolya	2	1
Müge	3	2
Kıyı	3	1
Zaman	2	0
Funda	3	0
Kırlangıç	5	4
Biricik	1	1
Saray	11	6
Gülay	4	0
Özen	6	0
Candaş	5	0
Egemen	4	3
Fesleğen	6	2
Şehit Ayhan Saybo	2	0
İspinoz	3	1
Yaprak	11	0
Reyhan	17	0
Lale	6	0
Açelya	16	0
TOTAL	**536**	**134**

Table B.4: Bağlarbaşı quarter - spatial distribution of damage table with respect to streets.

Street Name	Number of Building	Number of Collapsed Building
1. Ada	18	0
1. Bulut	7	0
2. Ada	4	0
2. Bulut	6	0
2. Fırat	2	0
Akasya	19	0
Artan	13	0
Aydınlar	1	0
Ayyılmaz	17	0
Bahar	1	0
Bayrak	13	0
Bulut	2	0
Burcu	7	0
Bülbül	7	0
Cemal Töre	6	0
Çöplük	7	0
Ekleme	3	0
Emin Töre Çıkmazı	4	0
Eski Bursa	20	0
Gedik	1	0
Gelincik	4	0
Gül	32	0
Gülerman	2	0
Güzel	35	0
Hanımeli	5	0
Işıl	3	0
İnan	7	0
Kamalye	7	0
Karanfil	6	0
Karaoğlu	5	0
Karaoğlu Çıkmazı	12	0
Lokman	5	0
Muhabbet Kuşu	14	0

Street Name	Number of Building	Number of Collapsed Building
Mutlu	12	0
Öner	4	0
Papatya	8	0
Radar	26	0
Rüzgar	9	0
Salkım	7	0
Sandıkçı	12	0
Selami-2. Çıkmaz	4	0
Sevim	1	0
Sönmez	7	0
Sümbül	10	0
Sümer	12	0
Şen	3	0
Tan	9	0
Tan Yokuş	17	0
Tandoğan	3	0
Taşçı	8	0
Tavuskuşu	7	0
Temasa	5	0
Tepe	4	0
Uçar	8	0
Yalçın	11	0
Yasemin	19	0
Yeni	1	0
Yıldırım	13	0
Yunus Emre	14	0
Yunus Emre 2. Çıkmaz	11	0
Yunus Emre 3. Çıkmaz	4	0
Yunus Emre 4. Çıkmaz	8	0
Yunus Emre 5. Çıkmaz	6	0

Table B.4: Bağlarbaşı quarter - spatial distribution of damage table with respect to streets (Cont'd).

Street Name	Number of Building	Number of Collapsed Building
Yunus Emre 6. Çıkmaz	3	0
Yunus Emre 7. Çıkmaz	10	0
Cantürk	2	0
Önder Çıkmazı	2	0
Çayır	15	1
Doğan Bey Çıkmazı	1	1
Kılıç	18	1
Kiraz	13	1
Menekşe	2	1
Selami	16	1
Söğüt	5	1
Yunus Emre 1. Çıkmaz	7	1
Çam	7	2
Bahçeli	3	3
Erişmen	12	3
Fırat	13	4
Nar	8	4
Koca Çayır 2.	21	5
Koca Çayır 1.	28	7
Eski Bursa	13	0
Vatan	18	2
Millet	16	1
Malazgirt	15	5
TOTAL	**810**	**44**

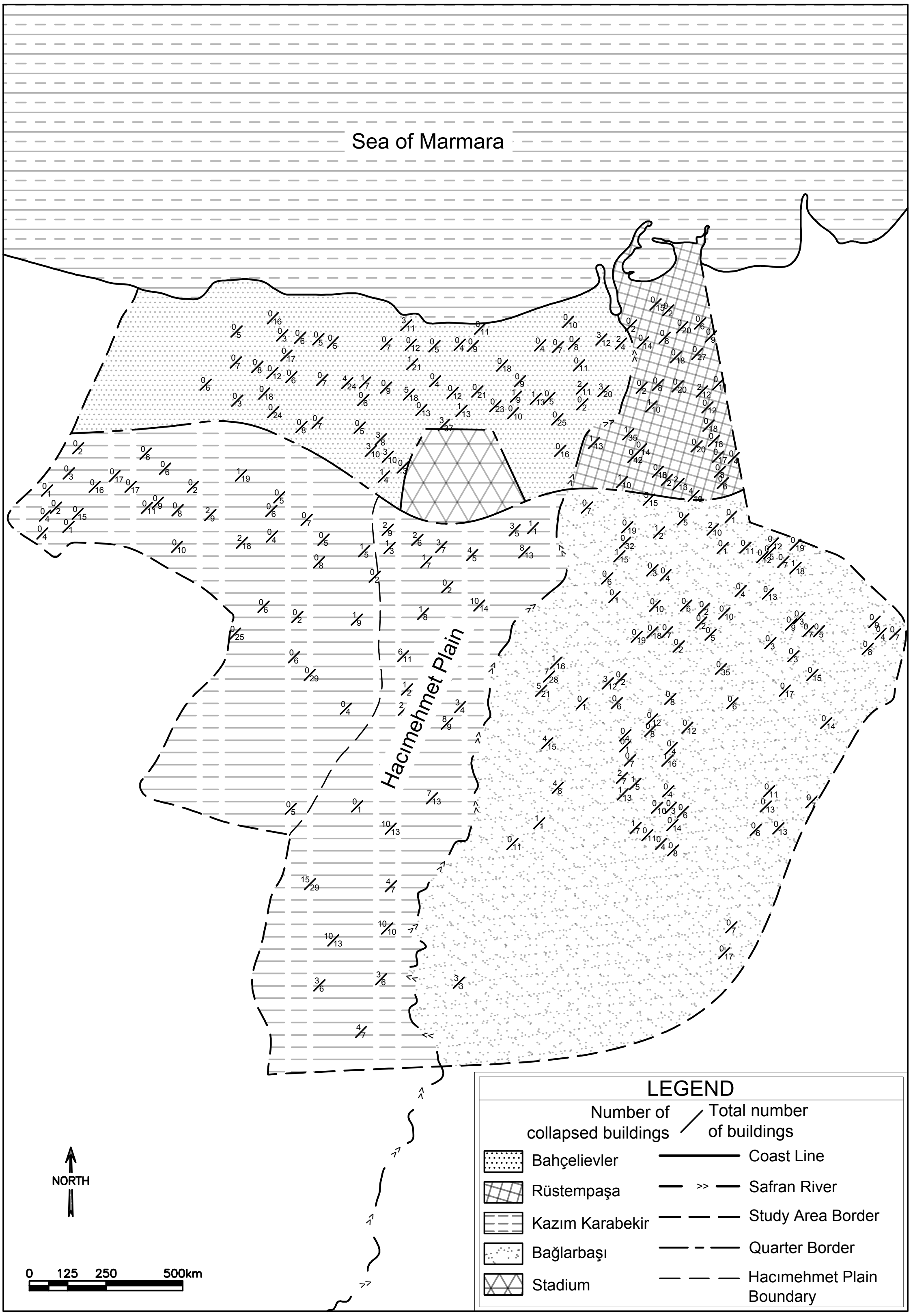

Figure B.1: Spatial distribution of damage (Numerical represantation of Figure 4.2).

APPENDIX C

LIQUEFACTION EVALUATION RESULTS

Table C.1: Borehole A1 - Liquefaction resistance calculations according to Youd et al. (2001) SPT procedure.

SPT Equipment Parameters		
Energy efficiency	=	60 %
Sampling method	=	Standard sampler
Borehole diameter	=	65-115 mm

Ground Motion Parameters		
Moment Magnitude, M_w	=	7.4
Peak Ground Acceleration, a_{max}	=	0.38 g

Ground Water Level =	0.3 m

Soil Properties					**SPT Corrections**						**Corrected SPT**		**Intermediate Calculations**													
SPT #	**z (m)**	**γ (kN/m²)**	**N_m**	**FC**	**lr (m)**	**C_N**	**C_E**	**C_B**	**C_R**	**C_S**	**$(N_1)_{60}$**	**$(N_1)_{60,CS}$**	**σ (kN/m²)**	**σ' (kN/m²)**	**D_{r1}**	**D_{r2}**	**$D_{r,ave}$**	**f**	**$K_σ$**	**r_d**	**MSF**	**CSR**	**$CRR_{7.5}$**	**FS**
1	4.7	18.0	36	34	7.7	1.36	1.00	1.00	0.95	1.00	47	60	85	41	90.0	90.0	90.0	0.6	1.00	0.964	1.03	0.489	(N1)60>30	3.00
2	6.2	18.0	16	34	9.2	1.27	1.00	1.00	0.95	1.00	19	28	112	54	64.7	64.6	64.7	0.7	1.00	0.952	1.03	0.491	0.364	**0.77**
3	7.7	18.6	16	25	10.7	1.18	1.00	1.00	1.00	1.00	19	25	140	67	64.0	63.9	64.0	0.7	1.00	0.941	1.03	0.486	0.297	**0.63**
4	9.2	18.0	5	25	12.2	1.10	1.00	1.00	1.00	1.00	6	10	167	79	34.7	33.5	34.1	0.8	1.00	0.928	1.03	0.483	0.117	**0.25**
5	10.7	18.0	27	25	13.7	1.04	1.00	1.00	1.00	1.00	28	36	194	91	78.2	77.4	77.8	0.7	1.00	0.888	1.03	0.465	(N1)60>30	Not Sand
6	12.2	18.4	50	7	15.2	0.98	1.00	1.00	1.00	1.00	49	49	222	104	90.0	90.0	90.0	0.6	0.98	0.848	1.03	0.444	(N1)60>30	3.00
7	13.7	18.0	44	7	16.7	0.93	1.00	1.00	1.00	1.00	41	41	249	117	90.0	90.0	90.0	0.6	0.94	0.808	1.03	0.425	(N1)60>30	3.00
8	15.7	18.0	35	67	18.7	0.87	1.00	1.00	1.00	1.00	30	42	285	133	81.3	79.9	80.6	0.6	0.89	0.754	1.03	0.398	(N1)60>30	Not Sand
9	16.7	18.0	39	67	19.7	0.84	1.00	1.00	1.00	1.00	33	44	303	141	84.5	82.4	83.4	0.6	0.87	0.727	1.03	0.385	(N1)60>30	Not Sand
10	18.2	18.0	R	93	21.2	0.80	1.00	1.00	1.00	1.00	R	R	330	153	90.0	90.0	90.0	0.6	0.84	0.687	1.03	0.365	(N1)60>30	Not Sand
11	19.7	18.0	R		22.7	0.77	1.00	1.00	1.00	1.00	R	R	357	166	90.0	90.0	90.0	0.6	0.82	0.647	1.03	0.344	(N1)60>30	Not Sand

Table C.2: Borehole A2 - Liquefaction resistance calculations according to Youd et al. (2001) SPT procedure.

SPT Equipment Parameters		
Energy efficiency	=	60 %
Sampling method	=	Standard sampler
Borehole diameter	=	65-115 mm

Ground Motion Parameters		
Moment Magnitude, M_w	=	7.4
Peak Ground Acceleration, a_{max}	=	0.38 g

Ground Water Level =	1.6 m

Soil Properties					**SPT Corrections**						**Corrected SPT**		**Intermediate Calculations**												**FS**
SPT #	**z (m)**	**γ (kN/m²)**	**N_m**	**FC**	**lr (m)**	**C_N**	**C_E**	**C_B**	**C_R**	**C_S**	**$(N_1)_{60}$**	**$(N_1)_{60,CS}$**	**σ (kN/m²)**	**σ' (kN/m²)**	**D_{r1}**	**D_{r2}**	**$D_{r,ave}$**	**f**	**$K_σ$**	**r_d**	**MSF**	**CSR**	**$CRR_{7.5}$**		
1	1.7	18.0	8	5	4.7	1.47	1.00	1.00	0.85	1.00	10	10	31	30	46.6	46.2	46.4	0.7	1.00	0.987	1.03	0.254	0.113		Not Sand
2	3.2	18.0	23	6	6.2	1.36	1.00	1.00	0.95	1.00	30	30	58	42	80.3	79.1	79.7	0.7	1.00	0.975	1.03	0.332	0.456		1.42
3	4.7	17.9	24	6	7.7	1.26	1.00	1.00	0.95	1.00	29	29	85	54	79.1	78.2	78.7	0.7	1.00	0.964	1.03	0.373	0.409		1.13
4	6.2	18.0	14	6	9.2	1.18	1.00	1.00	0.95	1.00	16	16	112	66	58.4	58.1	58.2	0.7	1.00	0.952	1.03	0.396	0.168		**0.44**
5	7.7	18.0	32	6	10.7	1.11	1.00	1.00	1.00	1.00	35	36	139	79	87.8	85.0	86.4	0.6	1.00	0.941	1.03	0.410	(N1)60>30		3.00
6	9.2	18.0	20	6	12.2	1.04	1.00	1.00	1.00	1.00	21	21	166	91	67.3	67.4	67.4	0.7	1.00	0.928	1.03	0.417	0.228		**0.56**
7	10.7	18.0	14	92	13.7	0.99	1.00	1.00	1.00	1.00	14	22	193	103	54.8	54.4	54.6	0.7	0.99	0.888	1.03	0.409	0.236		Not Sand
8	12.2	18.0	22		15.2	0.93	1.00	1.00	1.00	1.00	21	30	220	116	66.8	66.9	66.8	0.7	0.96	0.848	1.03	0.398	0.445		Not Sand
9	13.7	18.0	51	95	16.7	0.89	1.00	1.00	1.00	1.00	45	59	247	128	90.0	90.0	90.0	0.6	0.91	0.808	1.03	0.385	(N1)60>30		Not Sand
10	15.7	18.0	34		18.7	0.83	1.00	1.00	1.00	1.00	28	39	283	144	78.4	77.7	78.0	0.7	0.90	0.754	1.03	0.365	(N1)60>30		Not Sand
11	16.7	18.0	R		19.7	0.81	1.00	1.00	1.00	1.00	R	R	301	152	90.0	90.0	90.0	0.6	0.84	0.727	1.03	0.355	(N1)60>30		Not Sand
12	18.2	18.0	R		21.2	0.77	1.00	1.00	1.00	1.00	R	R	328	165	90.0	90.0	90.0	0.6	0.82	0.687	1.03	0.338	(N1)60>30		Not Sand
13	19.7	18.0	R		22.7	0.74	1.00	1.00	1.00	1.00	R	R	355	177	90.0	90.0	90.0	0.6	0.80	0.647	1.03	0.320	(N1)60>30		Not Sand

Table C.3: Borehole A3 - Liquefaction resistance calculations according to Youd et al. (2001) SPT procedure.

SPT Equipment Parameters		
Energy efficiency	=	60 %
Sampling method	=	Standard sampler
Borehole diameter	=	65-115 mm

Ground Motion Parameters		
Moment Magnitude, M_w	=	7.4
Peak Ground Acceleration, a_{max}	=	0.38 g

Ground Water Level =	2.2 m

Soil Properties					**SPT Corrections**						**Corrected SPT**		**Intermediate Calculations**													
SPT #	**z (m)**	**γ (kN/m²)**	**N_m**	**FC**	**lr (m)**	**C_N**	**C_E**	**C_B**	**C_R**	**C_S**	**$(N_1)_{60}$**	**$(N_1)_{60,CS}$**	**σ (kN/m²)**	**σ' (kN/m²)**	**D_{r1}**	**D_{r2}**	**$D_{r,ave}$**	**f**	**$K_σ$**	**r_d**	**MSF**	**CSR**	**$CRR_{7.5}$**	**FS**
1	1.7	18.0	15	7	4.7	1.46	1.00	1.00	0.85	1.00	19	19	31	31	63.5	63.4	63.5	0.7	1.00	0.987	1.03	0.244	0.202	3.00
2	3.2	17.3	31	7	6.2	1.32	1.00	1.00	0.95	1.00	39	39	57	47	90.0	88.7	89.4	0.6	1.00	0.975	1.03	0.295	(N1)60>30	3.00
3	4.7	18.0	26	7	7.7	1.23	1.00	1.00	0.95	1.00	30	31	84	59	81.3	79.9	80.6	0.6	1.00	0.964	1.03	0.340	(N1)60>30	3.00
4	6.2	18.0	25	25	9.2	1.15	1.00	1.00	0.95	1.00	27	35	111	71	77.1	76.5	76.8	0.7	1.00	0.952	1.03	0.367	(N1)60>30	3.00
5	7.7	18.0	2	25	10.7	1.08	1.00	1.00	1.00	1.00	2	7	138	83	21.7	17.2	19.4	0.8	1.00	0.941	1.03	0.384	0.085	**0.23**
6	9.2	18.0	27	25	12.2	1.02	1.00	1.00	1.00	1.00	28	35	165	96	77.4	76.8	77.1	0.7	1.00	0.928	1.03	0.395	(N1)60>30	3.00
7	10.7	18.0	40	98	13.7	0.96	1.00	1.00	1.00	1.00	39	51	192	108	90.0	88.4	89.2	0.6	0.97	0.888	1.03	0.390	(N1)60>30	Not Sand
8	12.2	18.0	R		15.2	0.92	1.00	1.00	1.00	1.00	R	R	219	120	90.0	90.0	90.0	0.6	0.93	0.848	1.03	0.381	(N1)60>30	Not Sand
9	13.7	18.0	R		16.7	0.87	1.00	1.00	1.00	1.00	R	R	246	133	90.0	90.0	90.0	0.6	0.89	0.808	1.03	0.370	(N1)60>30	Not Sand
10	15.7	18.0	R		18.7	0.82	1.00	1.00	1.00	1.00	R	R	282	149	90.0	90.0	90.0	0.6	0.85	0.754	1.03	0.353	(N1)60>30	Not Sand
11	16.7	18.0	R		19.7	0.79	1.00	1.00	1.00	1.00	R	R	300	157	90.0	90.0	90.0	0.6	0.83	0.727	1.03	0.343	(N1)60>30	Not Sand
12	18.2	18.0	R		21.2	0.76	1.00	1.00	1.00	1.00	R	R	327	169	90.0	90.0	90.0	0.6	0.81	0.687	1.03	0.328	(N1)60>30	Not Sand
13	19.7	18.0	R		22.7	0.73	1.00	1.00	1.00	1.00	R	R	354	182	90.0	90.0	90.0	0.6	0.79	0.647	1.03	0.312	(N1)60>30	Not Sand

Table C.4: Borehole A4 - Liquefaction resistance calculations according to Youd et al. (2001) SPT procedure.

SPT Equipment Parameters		
Energy efficiency	=	60 %
Sampling method	=	Standard sampler
Borehole diameter	=	65-115 mm

Ground Motion Parameters		
Moment Magnitude, M_w	=	7.4
Peak Ground Acceleration, a_{max}	=	0.38 g

Ground Water Level =	2.6 m

Soil Properties					**SPT Corrections**						**Corrected SPT**		**Intermediate Calculations**											
SPT #	**z (m)**	**γ (kN/m²)**	**N_m**	**FC**	**lr (m)**	**C_N**	**C_E**	**C_B**	**C_R**	**C_S**	**$(N_1)_{60}$**	**$(N_1)_{60,CS}$**	**σ (kN/m²)**	**σ' (kN/m²)**	**D_{r1}**	**D_{r2}**	**$D_{r,ave}$**	**f**	**$K_σ$**	**r_d**	**MSF**	**CSR**	**$CRR_{7.5}$**	**FS**
1	1.7	18.0	17	12	4.7	1.46	1.00	1.00	0.85	1.00	21	23	31	31	67.6	67.7	67.7	0.7	1.00	0.987	1.03	0.244	0.261	3.00
2	3.2	18.6	13	12	6.2	1.28	1.00	1.00	0.95	1.00	16	18	59	52	58.5	58.2	58.4	0.7	1.00	0.975	1.03	0.271	0.190	**0.72**
3	4.7	18.6	14	12	7.7	1.19	1.00	1.00	0.95	1.00	16	18	87	66	58.6	58.2	58.4	0.7	1.00	0.964	1.03	0.315	0.190	**0.62**
4	6.2	18.5	18	12	9.2	1.11	1.00	1.00	0.95	1.00	19	21	115	79	64.2	64.1	64.1	0.7	1.00	0.952	1.03	0.343	0.229	**0.69**
5	7.7	18.0	17	95	10.7	1.04	1.00	1.00	1.00	1.00	18	26	142	91	62.1	61.9	62.0	0.7	1.00	0.941	1.03	0.362	0.320	Not Sand
6	9.2	18.0	25		12.2	0.99	1.00	1.00	1.00	1.00	25	35	169	103	73.2	73.1	73.2	0.7	0.99	0.928	1.03	0.374	(N1)60>30	Not Sand
7	10.7	18.0	18		13.7	0.93	1.00	1.00	1.00	1.00	17	25	196	115	60.5	60.2	60.3	0.7	0.96	0.888	1.03	0.371	0.295	Not Sand
8	12.2	18.0	28		15.2	0.89	1.00	1.00	1.00	1.00	25	35	223	128	73.5	73.4	73.5	0.7	0.93	0.848	1.03	0.365	(N1)60>30	Not Sand
9	13.7	18.0	24		16.7	0.85	1.00	1.00	1.00	1.00	20	29	250	140	66.4	66.5	66.5	0.7	0.90	0.808	1.03	0.355	0.429	Not Sand
10	15.2	18.0	39		18.2	0.81	1.00	1.00	1.00	1.00	32	43	277	152	82.8	81.0	81.9	0.6	0.85	0.767	1.03	0.344	(N1)60>30	Not Sand
11	16.7	18.0	38		19.7	0.77	1.00	1.00	1.00	1.00	29	40	304	165	79.9	78.8	79.4	0.7	0.86	0.727	1.03	0.331	(N1)60>30	Not Sand
12	18.2	18.0	43		21.2	0.74	1.00	1.00	1.00	1.00	32	43	331	177	83.2	81.4	82.3	0.6	0.80	0.687	1.03	0.317	(N1)60>30	Not Sand
13	19.7	18.0	54		22.7	0.71	1.00	1.00	1.00	1.00	38	51	358	189	90.0	88.2	89.1	0.6	0.77	0.647	1.03	0.302	(N1)60>30	Not Sand

Table C.5: Borehole A5 - Liquefaction resistance calculations according to Youd et al. (2001) SPT procedure.

SPT Equipment Parameters	
Energy efficiency =	60 %
Sampling method =	Standard sampler
Borehole diameter =	65-115 mm

Ground Motion Parameters	
Moment Magnitude, M_w =	7.4
Peak Ground Acceleration, a_{max} =	0.38 g

Ground Water Level =	1.9 m

Soil Properties					SPT Corrections						Corrected SPT		Intermediate Calculations												FS
SPT #	z (m)	γ (kN/m²)	N_m	FC	lr (m)	C_N	C_E	C_B	C_R	C_S	$(N_1)_{60}$	$(N_1)_{60,CS}$	σ (kN/m²)	σ' (kN/m²)	D_{r1}	D_{r2}	$D_{r,ave}$	f	$K_σ$	r_d	MSF	CSR	$CRR_{7.5}$		
1	1.7	18.0	23	20	4.7	1.46	1.00	1.00	0.85	1.00	28	34	31	31	78.7	77.8	78.3	0.7	1.00	0.987	1.03	0.244	(N1)60>30		3.00
2	3.2	18.0	26	8	6.2	1.34	1.00	1.00	0.95	1.00	33	34	58	45	84.7	82.6	83.6	0.6	1.00	0.975	1.03	0.314	(N1)60>30		3.00
3	4.7	18.3	37	2	7.7	1.24	1.00	1.00	0.95	1.00	44	44	86	57	90.0	90.0	90.0	0.6	1.00	0.964	1.03	0.355	(N1)60>30		3.00
4	6.2	18.4	41	1	9.2	1.16	1.00	1.00	0.95	1.00	45	45	113	70	90.0	90.0	90.0	0.6	1.00	0.952	1.03	0.379	(N1)60>30		3.00
5	7.7	18.0	43		10.7	1.09	1.00	1.00	1.00	1.00	47	61	140	82	90.0	90.0	90.0	0.6	1.00	0.941	1.03	0.395	(N1)60>30		Not Sand
6	9.2	18.0	46	95	12.2	1.02	1.00	1.00	1.00	1.00	47	62	167	95	90.0	90.0	90.0	0.6	1.00	0.928	1.03	0.404	(N1)60>30		Not Sand
7	10.7	18.0	51		13.7	0.97	1.00	1.00	1.00	1.00	49	64	194	107	90.0	90.0	90.0	0.6	0.97	0.888	1.03	0.398	(N1)60>30		Not Sand
8	12.2	18.0	54		15.2	0.92	1.00	1.00	1.00	1.00	50	65	221	119	90.0	90.0	90.0	0.6	0.93	0.848	1.03	0.388	(N1)60>30		Not Sand
9	13.7	18.0	71		16.7	0.87	1.00	1.00	1.00	1.00	62	80	248	132	90.0	90.0	90.0	0.6	0.90	0.808	1.03	0.376	(N1)60>30		Not Sand
10	15.2	18.0	77		18.2	0.83	1.00	1.00	1.00	1.00	64	82	275	144	90.0	90.0	90.0	0.6	0.86	0.767	1.03	0.362	(N1)60>30		Not Sand
11	16.7	18.0	86		19.7	0.80	1.00	1.00	1.00	1.00	69	87	302	156	90.0	90.0	90.0	0.6	0.84	0.727	1.03	0.348	(N1)60>30		Not Sand
12	18.2	18.0	R		21.2	0.76	1.00	1.00	1.00	1.00	R	R	329	168	90.0	90.0	90.0	0.6	0.81	0.687	1.03	0.332	(N1)60>30		Not Sand
13	19.7	18.0	R		22.7	0.73	1.00	1.00	1.00	1.00	R	R	356	181	90.0	90.0	90.0	0.6	0.79	0.647	1.03	0.315	(N1)60>30		Not Sand

Table C.6: Borehole A6 - Liquefaction resistance calculations according to Youd et al. (2001) SPT procedure.

SPT Equipment Parameters		
Energy efficiency	=	60 %
Sampling method	=	Standard sampler
Borehole diameter	=	65-115 mm

Ground Motion Parameters		
Moment Magnitude, M_w	=	7.4
Peak Ground Acceleration, a_{max}	=	0.38 g

Ground Water Level =	2.3 m

Soil Properties					SPT Corrections						Corrected SPT		Intermediate Calculations												FS
SPT #	z (m)	γ (kN/m²)	N_m	FC	lr (m)	C_N	C_E	C_B	C_R	C_S	$(N_1)_{60}$	$(N_1)_{60,CS}$	σ (kN/m²)	σ' (kN/m²)	D_{r1}	D_{r2}	$D_{r,ave}$	f	K_σ	r_d	MSF	CSR	$CRR_{7.5}$		
1	1.7	18.0	24	16	4.7	1.46	1.00	1.00	0.85	1.00	30	34	31	31	80.4	79.2	79.8	0.7	1.00	0.987	1.03	0.244	(N1)60>30		3.00
2	3.2	18.4	35	16	6.2	1.30	1.00	1.00	0.95	1.00	43	48	59	50	90.0	90.0	90.0	0.6	1.00	0.975	1.03	0.286	(N1)60>30		3.00
3	4.7	18.0	44		7.7	1.21	1.00	1.00	0.95	1.00	51	66	86	62	90.0	90.0	90.0	0.6	1.00	0.964	1.03	0.330	(N1)60>30		3.00
4	6.2	18.7	26	23	9.2	1.13	1.00	1.00	0.95	1.00	28	35	114	75	77.8	77.1	77.5	0.7	1.00	0.952	1.03	0.356	(N1)60>30		3.00
5	7.7	18.0	23	23	10.7	1.06	1.00	1.00	1.00	1.00	24	31	141	87	72.8	72.8	72.8	0.7	1.00	0.941	1.03	0.374	(N1)60>30		3.00
6	9.2	18.0	24	23	12.2	1.00	1.00	1.00	1.00	1.00	24	31	168	100	72.3	72.3	72.3	0.7	1.00	0.928	1.03	0.386	(N1)60>30		3.00
7	10.7	18.0	30	94	13.7	0.95	1.00	1.00	1.00	1.00	28	39	195	112	78.6	77.8	78.2	0.7	0.97	0.888	1.03	0.381	(N1)60>30		Not Sand
8	12.2	18.0	35		15.2	0.90	1.00	1.00	1.00	1.00	32	43	222	124	82.8	81.1	81.9	0.6	0.92	0.848	1.03	0.374	(N1)60>30		Not Sand
9	13.7	18.0	41		16.7	0.86	1.00	1.00	1.00	1.00	35	47	249	137	87.4	84.7	86.1	0.6	0.88	0.808	1.03	0.363	(N1)60>30		Not Sand
10	15.2	18.0	44		18.2	0.82	1.00	1.00	1.00	1.00	36	48	276	149	88.5	85.6	87.0	0.6	0.85	0.767	1.03	0.351	(N1)60>30		Not Sand
11	16.7	18.0	45		19.7	0.78	1.00	1.00	1.00	1.00	35	47	303	161	87.5	84.8	86.1	0.6	0.83	0.727	1.03	0.338	(N1)60>30		Not Sand
12	18.2	18.0	49		21.2	0.75	1.00	1.00	1.00	1.00	37	49	330	173	89.4	86.4	87.9	0.6	0.80	0.687	1.03	0.323	(N1)60>30		Not Sand
13	19.7	18.0	56		22.7	0.72	1.00	1.00	1.00	1.00	40	53	357	186	90.0	90.0	90.0	0.6	0.78	0.647	1.03	0.307	(N1)60>30		Not Sand

Table C.7: Borehole A7 - Liquefaction resistance calculations according to Youd et al. (2001) SPT procedure.

SPT Equipment Parameters		
Energy efficiency	=	60 %
Sampling method	=	Standard sampler
Borehole diameter	=	65-115 mm

Ground Motion Parameters		
Moment Magnitude, M_w	=	7.4
Peak Ground Acceleration, a_{max}	=	0.38 g

Ground Water Level = 1.7 m

Soil Properties					**SPT Corrections**						**Corrected SPT**		**Intermediate Calculations**													
SPT #	**z (m)**	**γ (kN/m²)**	N_m	**FC**	**lr (m)**	C_N	C_E	C_B	C_R	C_S	$(N_1)_{60}$	$(N_1)_{60,CS}$	**σ (kN/m²)**	**σ' (kN/m²)**	D_{r1}	D_{r2}	$D_{r,ave}$	**f**	K_σ	r_d	**MSF**	**CSR**	$CRR_{7.5}$	**FS**
1	1.7	18.0	17	18	4.7	1.46	1.00	1.00	0.85	1.00	21	26	31	31	67.8	67.8	67.8	0.7	1.00	0.987	1.03	0.248	0.311	1.30
2	3.2	18.3	14	18	6.2	1.35	1.00	1.00	0.95	1.00	18	22	59	43	62.4	62.3	62.3	0.7	1.00	0.975	1.03	0.326	0.249	**0.79**
3	4.7	18.4	14	11	7.7	1.25	1.00	1.00	0.95	1.00	17	18	86	56	60.1	59.8	60.0	0.7	1.00	0.964	1.03	0.365	0.197	**0.56**
4	6.2	18.4	27	39	9.2	1.16	1.00	1.00	0.95	1.00	30	41	114	69	80.6	79.3	79.9	0.7	1.00	0.952	1.03	0.387	(N1)60>30	3.00
5	7.7	18.0	20	94	10.7	1.09	1.00	1.00	1.00	1.00	22	31	141	81	68.9	69.0	69.0	0.7	1.00	0.941	1.03	0.402	(N1)60>30	Not Sand
6	9.2	18.0	R		12.2	1.03	1.00	1.00	1.00	1.00	R	R	168	94	90.0	90.0	90.0	0.6	1.00	0.928	1.03	0.411	(N1)60>30	Not Sand
7	10.7	18.0	R		13.7	0.97	1.00	1.00	1.00	1.00	R	R	195	106	90.0	90.0	90.0	0.6	0.98	0.888	1.03	0.403	(N1)60>30	Not Sand
8	12.2	18.0	R		15.2	0.92	1.00	1.00	1.00	1.00	R	R	222	118	90.0	90.0	90.0	0.6	0.94	0.848	1.03	0.393	(N1)60>30	Not Sand
9	13.7	18.0	R		16.7	0.88	1.00	1.00	1.00	1.00	R	R	249	130	90.0	90.0	90.0	0.6	0.90	0.808	1.03	0.380	(N1)60>30	Not Sand
10	15.2	18.0	R		18.2	0.84	1.00	1.00	1.00	1.00	R	R	276	143	90.0	90.0	90.0	0.6	0.87	0.767	1.03	0.366	(N1)60>30	Not Sand
11	16.7	18.0	R		19.7	0.80	1.00	1.00	1.00	1.00	R	R	303	155	90.0	90.0	90.0	0.6	0.84	0.727	1.03	0.351	(N1)60>30	Not Sand

Table C.8: Borehole A8 - Liquefaction resistance calculations according to Youd et al. (2001) SPT procedure.

SPT Equipment Parameters		
Energy efficiency	=	60 %
Sampling method	=	Standard sampler
Borehole diameter	=	65-115 mm

Ground Motion Parameters		
Moment Magnitude, M_w	=	7.4
Peak Ground Acceleration, a_{max}	=	0.38 g

Ground Water Level =	3.7 m

Soil Properties					SPT Corrections						Corrected SPT		Intermediate Calculations												FS
SPT #	z (m)	γ (kN/m²)	N_m	FC	Ir (m)	C_N	C_E	C_B	C_R	C_S	$(N_1)_{60}$	$(N_1)_{60,CS}$	σ (kN/m²)	σ' (kN/m²)	D_{r1}	D_{r2}	$D_{r,ave}$	f	$K_σ$	r_d	MSF	CSR	$CRR_{7.5}$		
1	1.7	18.0	37	12	4.7	1.46	1.00	1.00	0.85	1.00	46	49	31	31	90.0	90.0	90.0	0.6	1.00	0.987	1.03	0.244	(N1)60>30		Not Sand
2	3.2	18.7	36	36	6.2	1.23	1.00	1.00	0.95	1.00	42	55	59	59	90.0	90.0	90.0	0.6	1.00	0.975	1.03	0.241	(N1)60>30		Not Sand
3	4.7	18.0	40	36	7.7	1.13	1.00	1.00	0.95	1.00	43	56	86	76	90.0	90.0	90.0	0.6	1.00	0.964	1.03	0.271	(N1)60>30		Not Sand
4	6.2	18.0	44		9.2	1.06	1.00	1.00	0.95	1.00	44	58	113	88	90.0	90.0	90.0	0.6	1.00	0.952	1.03	0.303	(N1)60>30		Not Sand
5	7.7	18.0	44	63	10.7	1.00	1.00	1.00	1.00	1.00	44	58	140	100	90.0	90.0	90.0	0.6	1.00	0.941	1.03	0.325	(N1)60>30		Not Sand
6	9.2	18.0	54		12.2	0.95	1.00	1.00	1.00	1.00	51	66	167	112	90.0	90.0	90.0	0.6	0.95	0.928	1.03	0.341	(N1)60>30		Not Sand
7	10.7	18.0	49		13.7	0.90	1.00	1.00	1.00	1.00	44	58	194	125	90.0	90.0	90.0	0.6	0.92	0.888	1.03	0.341	(N1)60>30		Not Sand
8	12.2	18.0	48		15.2	0.86	1.00	1.00	1.00	1.00	41	54	221	137	90.0	90.0	90.0	0.6	0.88	0.848	1.03	0.338	(N1)60>30		Not Sand
9	13.7	18.0	51	84	16.7	0.82	1.00	1.00	1.00	1.00	42	55	248	149	90.0	90.0	90.0	0.6	0.85	0.808	1.03	0.332	(N1)60>30		Not Sand
10	15.2	18.0	61		18.2	0.78	1.00	1.00	1.00	1.00	48	62	275	162	90.0	90.0	90.0	0.6	0.83	0.767	1.03	0.323	(N1)60>30		Not Sand
11	16.7	18.0	62		19.7	0.75	1.00	1.00	1.00	1.00	46	61	302	174	90.0	90.0	90.0	0.6	0.80	0.727	1.03	0.312	(N1)60>30		Not Sand
12	18.2	18.0	72		21.2	0.72	1.00	1.00	1.00	1.00	52	67	329	186	90.0	90.0	90.0	0.6	0.78	0.687	1.03	0.300	(N1)60>30		Not Sand
13	19.7	18.0	73	95	22.7	0.69	1.00	1.00	1.00	1.00	50	66	356	198	90.0	90.0	90.0	0.6	0.76	0.647	1.03	0.287	(N1)60>30		Not Sand

Table C.9: Borehole A9 - Liquefaction resistance calculations according to Youd et al. (2001) SPT procedure.

SPT Equipment Parameters		
Energy efficiency	=	60 %
Sampling method	=	Standard sampler
Borehole diameter	=	65-115 mm

Ground Motion Parameters		
Moment Magnitude, M_w	=	7.4
Peak Ground Acceleration, a_{max}	=	0.38 g

Ground Water Level =	0.3 m

Soil Properties					SPT Corrections						Corrected SPT		Intermediate Calculations											FS
SPT #	z (m)	γ (kN/m²)	N_m	FC	Ir (m)	C_N	C_E	C_B	C_R	C_S	$(N_1)_{60}$	$(N_1)_{60,CS}$	σ (kN/m²)	σ' (kN/m²)	D_{r1}	D_{r2}	$D_{r,ave}$	f	$K_σ$	r_d	MSF	CSR	$CRR_{7.5}$	
1	1.7	18.0	R		4.7	1.60	1.00	1.00	0.85	1.00	R	R	31	17	90.0	90.0	90.0	0.6	1.00	0.987	1.03	0.433	(N1)60>30	Not Sand
2	3.2	18.0	R	6	6.2	1.47	1.00	1.00	0.95	1.00	R	R	58	30	90.0	90.0	90.0	0.6	1.00	0.975	1.03	0.470	(N1)60>30	3.00
3	4.7	18.3	31	5	7.7	1.35	1.00	1.00	0.95	1.00	40	40	86	43	90.0	89.8	89.9	0.6	1.00	0.964	1.03	0.479	(N1)60>30	3.00
4	6.2	18.3	33	6	9.2	1.25	1.00	1.00	0.95	1.00	39	40	113	55	90.0	89.2	89.6	0.6	1.00	0.952	1.03	0.481	(N1)60>30	3.00
5	7.7	18.5	26	27	10.7	1.17	1.00	1.00	1.00	1.00	30	39	141	68	81.3	79.9	80.6	0.6	1.00	0.941	1.03	0.479	(N1)60>30	3.00
6	9.2	18.0	28		12.2	1.10	1.00	1.00	1.00	1.00	31	42	168	81	81.7	80.2	81.0	0.6	1.00	0.928	1.03	0.477	(N1)60>30	Not Sand
7	10.7	18.0	57	95	13.7	1.03	1.00	1.00	1.00	1.00	59	76	195	93	90.0	90.0	90.0	0.6	1.00	0.888	1.03	0.460	(N1)60>30	Not Sand
8	12.2	18.0	54		15.2	0.98	1.00	1.00	1.00	1.00	53	68	222	105	90.0	90.0	90.0	0.6	0.98	0.848	1.03	0.441	(N1)60>30	Not Sand
9	13.7	18.0	60		16.7	0.93	1.00	1.00	1.00	1.00	56	72	249	117	90.0	90.0	90.0	0.6	0.94	0.808	1.03	0.422	(N1)60>30	Not Sand
10	15.2	18.0	63	96	18.2	0.88	1.00	1.00	1.00	1.00	55	72	276	130	90.0	90.0	90.0	0.6	0.90	0.767	1.03	0.403	(N1)60>30	Not Sand
11	16.7	18.0	61		19.7	0.84	1.00	1.00	1.00	1.00	51	66	303	142	90.0	90.0	90.0	0.6	0.87	0.727	1.03	0.383	(N1)60>30	Not Sand
12	18.2	18.0	76		21.2	0.80	1.00	1.00	1.00	1.00	61	78	330	154	90.0	90.0	90.0	0.6	0.84	0.687	1.03	0.363	(N1)60>30	Not Sand
13	19.7	18.0	84	95	22.7	0.77	1.00	1.00	1.00	1.00	64	82	357	167	90.0	90.0	90.0	0.6	0.82	0.647	1.03	0.342	(N1)60>30	Not Sand

Table C.10: Borehole A10 - Liquefaction resistance calculations according to Youd et al. (2001) SPT procedure.

SPT Equipment Parameters		
Energy efficiency	=	60 %
Sampling method	=	Standard sampler
Borehole diameter	=	65-115 mm

Ground Motion Parameters		
Moment Magnitude, M_w	=	7.4
Peak Ground Acceleration, a_{max}	=	0.38 g

Ground Water Level =	3.3 m

Soil Properties					SPT Corrections						Corrected SPT		Intermediate Calculations											FS
SPT #	z (m)	γ (kN/m²)	N_m	FC	lr (m)	C_N	C_E	C_B	C_R	C_S	$(N_1)_{60}$	$(N_1)_{60,CS}$	σ (kN/m²)	σ' (kN/m²)	D_{r1}	D_{r2}	$D_{r,ave}$	f	$K_σ$	r_d	MSF	CSR	$CRR_{7.5}$	
1	1.7	18.0	14	81	4.7	1.46	1.00	1.00	0.85	1.00	17	26	31	31	61.4	61.2	61.3	0.7	1.00	0.987	1.03	0.244	0.309	Not Sand
2	3.2	18.5	19	14	6.2	1.23	1.00	1.00	0.95	1.00	22	25	59	59	69.5	69.6	69.5	0.7	1.00	0.975	1.03	0.241	0.299	3.00
3	4.7	18.6	36	76	7.7	1.14	1.00	1.00	0.95	1.00	39	52	87	72	90.0	89.0	89.5	0.6	1.00	0.964	1.03	0.285	(N1)60>30	3.00
4	6.2	18.0	10	16	9.2	1.07	1.00	1.00	0.95	1.00	10	14	114	85	47.1	46.8	46.9	0.7	1.00	0.952	1.03	0.315	0.145	**0.48**
5	7.7	18.0	13	97	10.7	1.01	1.00	1.00	1.00	1.00	13	21	141	97	53.5	53.1	53.3	0.7	1.00	0.941	1.03	0.337	0.226	Not Sand
6	9.2	18.0	18	97	12.2	0.96	1.00	1.00	1.00	1.00	17	26	168	109	61.3	61.1	61.2	0.7	0.97	0.928	1.03	0.351	0.307	Not Sand
7	10.7	18.0	24	97	13.7	0.91	1.00	1.00	1.00	1.00	22	31	195	122	68.9	69.0	69.0	0.7	0.94	0.888	1.03	0.351	(N1)60>30	Not Sand
8	12.2	18.0	30	97	15.2	0.87	1.00	1.00	1.00	1.00	26	36	222	134	75.2	74.9	75.0	0.7	0.92	0.848	1.03	0.347	(N1)60>30	Not Sand
9	13.7	18.0	R		16.7	0.83	1.00	1.00	1.00	1.00	R	R	249	146	90.0	90.0	90.0	0.6	0.86	0.808	1.03	0.339	(N1)60>30	Not Sand
10	15.2	18.0	R		18.2	0.79	1.00	1.00	1.00	1.00	R	R	276	158	90.0	90.0	90.0	0.6	0.83	0.767	1.03	0.330	(N1)60>30	Not Sand
11	16.7	18.0	R		19.7	0.76	1.00	1.00	1.00	1.00	R	R	303	171	90.0	90.0	90.0	0.6	0.81	0.727	1.03	0.319	(N1)60>30	Not Sand
12	18.2	18.0	R		21.2	0.73	1.00	1.00	1.00	1.00	R	R	330	183	90.0	90.0	90.0	0.6	0.79	0.687	1.03	0.306	(N1)60>30	Not Sand
13	19.7	18.0	R		22.7	0.70	1.00	1.00	1.00	1.00	R	R	357	195	90.0	90.0	90.0	0.6	0.77	0.647	1.03	0.292	(N1)60>30	Not Sand
14	21.2	18.0	R		24.2	0.67	1.00	1.00	1.00	1.00	R	R	384	208	90.0	90.0	90.0	0.6	0.75	0.607	1.03	0.277	(N1)60>30	Not Sand

Table C.11: Borehole A11 - Liquefaction resistance calculations according to Youd et al. (2001) SPT procedure.

SPT Equipment Parameters	
Energy efficiency =	60 %
Sampling method =	Standard sampler
Borehole diameter =	65-115 mm

Ground Motion Parameters	
Moment Magnitude, M_w =	7.4
Peak Ground Acceleration, a_{max} =	0.38 g

Ground Water Level =	1.7 m

Soil Properties					SPT Corrections						Corrected SPT		Intermediate Calculations											FS
SPT #	z (m)	γ (kN/m²)	N_m	FC	lr (m)	C_N	C_E	C_B	C_R	C_S	$(N_1)_{60}$	$(N_1)_{60,CS}$	σ (kN/m²)	σ' (kN/m²)	D_{r1}	D_{r2}	$D_{r,ave}$	f	$K_σ$	r_d	MSF	CSR	$CRR_{7.5}$	
1	1.7	18.0	16	21	4.7	1.46	1.00	1.00	0.85	1.00	20	25	31	31	65.7	65.7	65.7	0.7	1.00	0.987	1.03	0.246	0.297	Not Sand
2	3.2	18.0	23	21	6.2	1.35	1.00	1.00	0.95	1.00	29	36	58	43	80.0	78.9	79.5	0.7	1.00	0.975	1.03	0.325	(N1)60>30	3.00
3	4.7	18.5	16	21	7.7	1.25	1.00	1.00	0.95	1.00	19	24	86	56	64.2	64.2	64.2	0.7	1.00	0.964	1.03	0.364	0.279	**0.79**
4	6.2	18.0	22	16	9.2	1.17	1.00	1.00	0.95	1.00	24	28	113	68	72.8	72.8	72.8	0.7	1.00	0.952	1.03	0.388	0.387	1.03
5	7.7	18.6	42	40	10.7	1.09	1.00	1.00	1.00	1.00	46	60	141	82	90.0	90.0	90.0	0.6	1.00	0.941	1.03	0.401	(N1)60>30	3.00
6	9.2	18.0	79	57	12.2	1.03	1.00	1.00	1.00	1.00	81	103	168	94	90.0	90.0	90.0	0.6	1.00	0.928	1.03	0.409	(N1)60>30	Not Sand
7	10.7	18.0	R		13.7	0.97	1.00	1.00	1.00	1.00	R	R	195	106	90.0	90.0	90.0	0.6	0.98	0.888	1.03	0.402	(N1)60>30	Not Sand
8	12.2	18.0	R		15.2	0.92	1.00	1.00	1.00	1.00	R	R	222	118	90.0	90.0	90.0	0.6	0.93	0.848	1.03	0.392	(N1)60>30	Not Sand
9	13.7	18.0	R		16.7	0.88	1.00	1.00	1.00	1.00	R	R	249	131	90.0	90.0	90.0	0.6	0.90	0.808	1.03	0.379	(N1)60>30	Not Sand
10	15.2	18.0	R		18.2	0.84	1.00	1.00	1.00	1.00	R	R	276	143	90.0	90.0	90.0	0.6	0.87	0.767	1.03	0.365	(N1)60>30	Not Sand
11	16.7	18.0	R		19.7	0.80	1.00	1.00	1.00	1.00	R	R	303	155	90.0	90.0	90.0	0.6	0.84	0.727	1.03	0.350	(N1)60>30	Not Sand

Table C.12: Borehole A12 - Liquefaction resistance calculations according to Youd et al. (2001) SPT procedure.

SPT Equipment Parameters		
Energy efficiency	=	60 %
Sampling method	=	Standard sampler
Borehole diameter	=	65-115 mm

Ground Motion Parameters		
Moment Magnitude, M_w	=	7.4
Peak Ground Acceleration, a_{max}	=	0.38 g

Ground Water Level =	0.0 m

Soil Properties					SPT Corrections						Corrected SPT		Intermediate Calculations												FS
SPT #	z (m)	γ (kN/m²)	N_m	FC	lr (m)	C_N	C_E	C_B	C_R	C_S	$(N_1)_{60}$	$(N_1)_{60,CS}$	σ (kN/m²)	σ' (kN/m²)	D_{r1}	D_{r2}	$D_{r,ave}$	f	K_σ	r_d	MSF	CSR	$CRR_{7.5}$	
1	1.7	18.0	22		4.7	1.64	1.00	1.00	0.85	1.00	31	42	31	14	81.6	80.1	80.8	0.6	1.00	0.987	1.03	0.525	(N1)60>30	Not Sand
2	3.2	18.0	37		6.2	1.50	1.00	1.00	0.95	1.00	53	68	58	27	90.0	90.0	90.0	0.6	1.00	0.975	1.03	0.524	(N1)60>30	Not Sand
3	4.7	18.3	33	4	7.7	1.38	1.00	1.00	0.95	1.00	43	43	86	39	90.0	90.0	90.0	0.6	1.00	0.964	1.03	0.516	(N1)60>30	3.00
4	6.2	18.0	24	12	9.2	1.28	1.00	1.00	0.95	1.00	29	31	113	52	79.7	78.6	79.2	0.7	1.00	0.952	1.03	0.511	(N1)60>30	3.00
5	7.7	18.4	24	12	10.7	1.19	1.00	1.00	1.00	1.00	29	31	140	65	78.9	78.0	78.4	0.7	1.00	0.941	1.03	0.504	(N1)60>30	3.00
6	9.2	18.4	26	7	12.2	1.11	1.00	1.00	1.00	1.00	29	29	168	77	79.4	78.4	78.9	0.7	1.00	0.928	1.03	0.496	0.423	**0.88**
7	10.7	18.0	28	12	13.7	1.05	1.00	1.00	1.00	1.00	29	32	195	90	79.9	78.8	79.4	0.7	1.00	0.888	1.03	0.476	(N1)60>30	3.00
8	12.2	18.4	30	8	15.2	0.99	1.00	1.00	1.00	1.00	30	30	222	103	80.3	79.1	79.7	0.7	0.99	0.848	1.03	0.454	(N1)60>30	3.00
9	13.7	18.0	30	12	16.7	0.94	1.00	1.00	1.00	1.00	28	30	249	115	78.2	77.4	77.8	0.7	0.96	0.808	1.03	0.433	(N1)60>30	3.00
10	15.2	18.0	32	12	18.2	0.89	1.00	1.00	1.00	1.00	28	31	276	127	78.7	77.9	78.3	0.7	0.93	0.767	1.03	0.412	(N1)60>30	3.00
11	16.7	18.4	33	11	19.7	0.85	1.00	1.00	1.00	1.00	28	30	304	140	77.9	77.2	77.6	0.7	0.90	0.727	1.03	0.390	0.462	Not Sand
12	18.2	18.0	4	92	21.2	0.81	1.00	1.00	1.00	1.00	3	9	331	152	26.5	23.4	24.9	0.8	0.92	0.687	1.03	0.369	0.103	Not Sand
13	19.7	18.0	7		22.7	0.77	1.00	1.00	1.00	1.00	5	11	358	165	34.3	33.1	33.7	0.8	0.91	0.647	1.03	0.348	0.127	Not Sand
14	21.2	18.0	5		24.2	0.74	1.00	1.00	1.00	1.00	4	9	385	177	28.4	25.8	27.1	0.8	0.89	0.607	1.03	0.326	0.108	Not Sand

Table C.13: Borehole A13 - Liquefaction resistance calculations according to Youd et al. (2001) SPT procedure.

SPT Equipment Parameters		
Energy efficiency	=	60 %
Sampling method	=	Standard sampler
Borehole diameter	=	65-115 mm

Ground Motion Parameters		
Moment Magnitude, M_w	=	7.4
Peak Ground Acceleration, a_{max}	=	0.38 g

Ground Water Level	=	2.1 m

Soil Properties					SPT Corrections						Corrected SPT		Intermediate Calculations												
SPT #	z (m)	γ (kN/m²)	N_m	FC	lr (m)	C_N	C_E	C_B	C_R	C_S	$(N_1)_{60}$	$(N_1)_{60,CS}$	σ (kN/m²)	σ' (kN/m²)	D_{r1}	D_{r2}	$D_{r,ave}$	f	$K_σ$	r_d	MSF	CSR	$CRR_{7.5}$	FS
1	1.7	18.0	4		4.7	1.46	1.00	1.00	0.85	1.00	5	11	31	31	32.8	31.3	32.0	0.8	1.00	0.987	1.03	0.244	0.122	Not Sand
2	3.2	18.0	R	12	6.2	1.32	1.00	1.00	0.95	1.00	R	R	58	47	90.0	90.0	90.0	0.6	1.00	0.975	1.03	0.297	(N1)60>30	Not Sand
3	4.7	17.5	48	16	7.7	1.23	1.00	1.00	0.95	1.00	56	62	84	58	90.0	90.0	90.0	0.6	1.00	0.964	1.03	0.343	(N1)60>30	3.00
4	6.2	17.7	39	11	9.2	1.16	1.00	1.00	0.95	1.00	43	45	111	70	90.0	90.0	90.0	0.6	1.00	0.952	1.03	0.370	(N1)60>30	3.00
5	7.7	18.0	R	15	10.7	1.09	1.00	1.00	1.00	1.00	R	R	138	83	90.0	90.0	90.0	0.6	1.00	0.941	1.03	0.388	(N1)60>30	3.00
6	9.2	18.0	R	15	12.2	1.02	1.00	1.00	1.00	1.00	R	R	165	95	90.0	90.0	90.0	0.6	1.00	0.928	1.03	0.398	(N1)60>30	3.00
7	10.7	18.0	58	15	13.7	0.97	1.00	1.00	1.00	1.00	56	61	192	107	90.0	90.0	90.0	0.6	0.97	0.888	1.03	0.392	(N1)60>30	3.00
8	12.2	18.1	11	33	15.2	0.92	1.00	1.00	1.00	1.00	10	17	219	120	46.8	46.5	46.7	0.7	0.95	0.848	1.03	0.383	0.178	**0.46**
9	13.7	18.0	8		16.7	0.87	1.00	1.00	1.00	1.00	7	13	246	132	39.0	38.4	38.7	0.8	0.95	0.808	1.03	0.372	0.144	Not Sand
10	16.7	18.0	4	91	19.7	0.80	1.00	1.00	1.00	1.00	3	9	300	157	26.3	23.1	24.7	0.8	0.91	0.727	1.03	0.344	0.103	Not Sand
11	18.2	18.0	6	98	21.2	0.76	1.00	1.00	1.00	1.00	5	10	327	169	31.5	29.7	30.6	0.8	0.90	0.687	1.03	0.329	0.117	Not Sand
12	19.7	18.0	5		22.7	0.73	1.00	1.00	1.00	1.00	4	9	354	181	28.2	25.5	26.9	0.8	0.89	0.647	1.03	0.313	0.108	Not Sand
13	21.2	18.0	6	98	24.2	0.70	1.00	1.00	1.00	1.00	4	10	381	193	30.3	28.1	29.2	0.8	0.88	0.607	1.03	0.296	0.114	Not Sand
14	22.7	18.0	6		25.7	0.68	1.00	1.00	1.00	1.00	4	10	408	206	29.7	27.4	28.6	0.8	0.87	0.567	1.03	0.278	0.112	Not Sand

Table C.14: Borehole A14 - Liquefaction resistance calculations according to Youd et al. (2001) SPT procedure.

SPT Equipment Parameters		
Energy efficiency	=	60 %
Sampling method	=	Standard sampler
Borehole diameter	=	65-115 mm

Ground Motion Parameters		
Moment Magnitude, M_w	=	7.4
Peak Ground Acceleration, a_{max}	=	0.38 g

Ground Water Level =	0.5 m

Soil Properties					**SPT Corrections**						**Corrected SPT**		**Intermediate Calculations**											
SPT #	**z (m)**	**γ (kN/m²)**	**N_m**	**FC**	**Ir (m)**	**C_N**	**C_E**	**C_B**	**C_R**	**C_S**	**$(N_1)_{60}$**	**$(N_1)_{60,CS}$**	**σ (kN/m²)**	**σ' (kN/m²)**	**D_{r1}**	**D_{r2}**	**$D_{r,ave}$**	**f**	**$K_σ$**	**r_d**	**MSF**	**CSR**	**$CRR_{7.5}$**	**FS**
1	1.7	18.0	20	5	4.7	1.58	1.00	1.00	0.85	1.00	27	27	31	19	76.4	75.9	76.1	0.7	1.00	0.987	1.03	0.390	0.335	**0.89**
2	3.2	18.0	34	5	6.2	1.45	1.00	1.00	0.95	1.00	47	47	58	32	90.0	90.0	90.0	0.6	1.00	0.975	1.03	0.441	(N1)60>30	3.00
3	4.7	18.4	36	5	7.7	1.34	1.00	1.00	0.95	1.00	46	46	86	45	90.0	90.0	90.0	0.6	1.00	0.964	1.03	0.458	(N1)60>30	3.00
4	6.2	18.0	20	5	9.2	1.24	1.00	1.00	0.95	1.00	24	24	113	57	71.7	71.7	71.7	0.7	1.00	0.952	1.03	0.466	0.268	**0.59**
5	7.7	18.0	22	4	10.7	1.16	1.00	1.00	1.00	1.00	26	26	140	69	74.6	74.4	74.5	0.7	1.00	0.941	1.03	0.469	0.304	**0.67**
6	9.2	18.4	25	4	12.2	1.09	1.00	1.00	1.00	1.00	27	27	167	82	76.9	76.4	76.7	0.7	1.00	0.928	1.03	0.467	0.345	**0.76**
7	10.7	18.0	6		13.7	1.03	1.00	1.00	1.00	1.00	6	12	194	94	36.6	35.7	36.2	0.8	1.00	0.888	1.03	0.452	0.135	Not Sand
8	12.2	18.0	18		15.2	0.97	1.00	1.00	1.00	1.00	17	26	221	107	61.6	61.5	61.6	0.7	0.98	0.848	1.03	0.435	0.313	Not Sand
9	13.7	18.0	12		16.7	0.92	1.00	1.00	1.00	1.00	11	18	248	119	49.0	48.7	48.8	0.7	0.95	0.808	1.03	0.417	0.195	Not Sand
10	15.2	18.6	17	31	18.2	0.87	1.00	1.00	1.00	1.00	15	22	276	132	56.8	56.4	56.6	0.7	0.92	0.767	1.03	0.397	0.242	**0.58**
11	16.7	18.0	18	7	19.7	0.83	1.00	1.00	1.00	1.00	15	15	303	144	57.1	56.7	56.9	0.7	0.90	0.727	1.03	0.377	0.163	**0.40**
12	18.2	18.0	20	7	21.2	0.80	1.00	1.00	1.00	1.00	16	16	330	157	58.8	58.5	58.7	0.7	0.87	0.687	1.03	0.358	0.172	**0.44**
13	19.7	18.5	24	7	22.7	0.76	1.00	1.00	1.00	1.00	18	19	358	170	63.0	62.8	62.9	0.7	0.85	0.647	1.03	0.337	0.198	**0.52**
14	21.2	18.0	26	7	24.2	0.73	1.00	1.00	1.00	1.00	19	19	385	182	64.2	64.1	64.2	0.7	0.84	0.607	1.03	0.317	0.206	**0.56**
15	24.2	18.0	27	95	27.2	0.67	1.00	1.00	1.00	1.00	18	27	439	206	62.9	62.8	62.8	0.7	0.80	z>23m	1.03		0.334	Not Sand

Table C.15: Borehole A15 - Liquefaction resistance calculations according to Youd et al. (2001) SPT procedure.

SPT Equipment Parameters		
Energy efficiency	=	60 %
Sampling method	=	Standard sampler
Borehole diameter	=	65-115 mm

Ground Motion Parameters		
Moment Magnitude, M_w	=	7.4
Peak Ground Acceleration, a_{max}	=	0.38 g

Ground Water Level =	0.5 m

Soil Properties					SPT Corrections						Corrected SPT		Intermediate Calculations											
SPT #	z (m)	γ (kN/m²)	N_m	FC	lr (m)	C_N	C_E	C_B	C_R	C_S	$(N_1)_{60}$	$(N_1)_{60,CS}$	σ (kN/m²)	σ' (kN/m²)	D_{r1}	D_{r2}	$D_{r,ave}$	f	$K_σ$	r_d	MSF	CSR	$CRR_{7.5}$	FS
1	1.7	18.0	R	12	4.7	1.58	1.00	1.00	0.85	1.00	R	R	31	19	90.0	90.0	90.0	0.6	1.00	0.987	1.03	0.394	(N1)60>30	3.00
2	3.2	18.3	29	12	6.2	1.45	1.00	1.00	0.95	1.00	40	42	59	32	90.0	89.8	89.9	0.6	1.00	0.975	1.03	0.441	(N1)60>30	3.00
3	4.7	18.0	7	9	7.7	1.34	1.00	1.00	0.95	1.00	9	10	86	44	44.0	43.6	43.8	0.7	1.00	0.964	1.03	0.460	0.109	**0.24**
4	6.2	18.0	21	9	9.2	1.25	1.00	1.00	0.95	1.00	25	26	113	57	73.5	73.4	73.5	0.7	1.00	0.952	1.03	0.468	0.307	**0.68**
5	7.7	18.4	18	5	10.7	1.16	1.00	1.00	1.00	1.00	21	21	140	69	67.4	67.5	67.4	0.7	1.00	0.941	1.03	0.469	0.228	**0.50**
6	10.7	18.0	18	5	13.7	1.03	1.00	1.00	1.00	1.00	19	19	194	94	63.4	63.3	63.4	0.7	1.00	0.888	1.03	0.453	0.198	**0.45**
7	12.2	18.0	60	63	15.2	0.97	1.00	1.00	1.00	1.00	58	75	221	106	90.0	90.0	90.0	0.6	0.98	0.848	1.03	0.435	(N1)60>30	3.00
8	13.7	18.0	87	63	16.7	0.92	1.00	1.00	1.00	1.00	80	101	248	119	90.0	90.0	90.0	0.6	0.93	0.808	1.03	0.417	(N1)60>30	3.00
9	15.2	18.0	49	63	18.2	0.88	1.00	1.00	1.00	1.00	43	57	275	131	90.0	90.0	90.0	0.6	0.90	0.767	1.03	0.398	(N1)60>30	3.00
10	16.7	18.0	48	63	19.7	0.84	1.00	1.00	1.00	1.00	40	53	302	143	90.0	90.0	90.0	0.6	0.87	0.727	1.03	0.379	(N1)60>30	3.00
11	18.2	18.0	24		21.2	0.80	1.00	1.00	1.00	1.00	19	28	329	155	64.6	64.5	64.5	0.7	0.88	0.687	1.03	0.359	0.370	Not Sand
12	19.7	18.0	30		22.7	0.76	1.00	1.00	1.00	1.00	23	33	356	168	70.6	70.7	70.6	0.7	0.86	0.647	1.03	0.339	(N1)60>30	Not Sand
13	22.7	18.0	14	86	25.7	0.70	1.00	1.00	1.00	1.00	10	17	410	192	46.3	46.0	46.1	0.7	0.82	0.567	1.03	0.299	0.179	Not Sand
14	25.7	18.0	31		28.7	0.65	1.00	1.00	1.00	1.00	20	29	464	217	66.3	66.4	66.3	0.7	0.79	z>23m	1.03		0.425	Not Sand

Table C.16: Borehole A16 - Liquefaction resistance calculations according to Youd et al. (2001) SPT procedure.

SPT Equipment Parameters		
Energy efficiency	=	60 %
Sampling method	=	Standard sampler
Borehole diameter	=	65-115 mm

Ground Motion Parameters		
Moment Magnitude, M_w	=	7.4
Peak Ground Acceleration, a_{max}	=	0.38 g

Ground Water Level =	2.2 m

Soil Properties					SPT Corrections						Corrected SPT		Intermediate Calculations												FS
SPT #	z (m)	γ (kN/m²)	N_m	FC	lr (m)	C_N	C_E	C_B	C_R	C_S	$(N_1)_{60}$	$(N_1)_{60,CS}$	σ (kN/m²)	σ' (kN/m²)	D_{r1}	D_{r2}	$D_{r,ave}$	f	$K_σ$	r_d	MSF	CSR	$CRR_{7.5}$		
1	1.7	18.0	28	12	4.7	1.46	1.00	1.00	0.85	1.00	35	37	31	31	86.8	84.2	85.5	0.6	1.00	0.987	1.03	0.244	(N1)60>30		3.00
2	3.2	18.0	33	13	6.2	1.31	1.00	1.00	0.95	1.00	41	45	58	48	90.0	90.0	90.0	0.6	1.00	0.975	1.03	0.293	(N1)60>30		3.00
3	4.7	18.4	37	23	7.7	1.22	1.00	1.00	0.95	1.00	43	51	86	61	90.0	90.0	90.0	0.6	1.00	0.964	1.03	0.336	(N1)60>30		3.00
4	6.2	18.0	27		9.2	1.14	1.00	1.00	0.95	1.00	29	40	113	73	79.7	78.7	79.2	0.7	1.00	0.952	1.03	0.363	(N1)60>30		Not Sand
5	7.7	18.5	31	23	10.7	1.07	1.00	1.00	1.00	1.00	33	40	140	86	84.8	82.6	83.7	0.6	1.00	0.941	1.03	0.379	(N1)60>30		Not Sand
6	9.2	18.0	31		12.2	1.01	1.00	1.00	1.00	1.00	31	42	167	98	82.4	80.8	81.6	0.6	1.00	0.928	1.03	0.390	(N1)60>30		Not Sand
7	10.7	18.0	30		13.7	0.95	1.00	1.00	1.00	1.00	29	39	194	111	78.9	78.0	78.4	0.7	0.97	0.888	1.03	0.385	(N1)60>30		Not Sand
8	12.2	18.0	27		15.2	0.91	1.00	1.00	1.00	1.00	24	34	221	123	72.9	72.9	72.9	0.7	0.94	0.848	1.03	0.377	(N1)60>30		Not Sand
9	13.7	18.0	14		16.7	0.86	1.00	1.00	1.00	1.00	12	19	248	135	51.2	50.8	51.0	0.7	0.91	0.808	1.03	0.367	0.209		Not Sand
10	15.2	18.0	9	86	18.2	0.82	1.00	1.00	1.00	1.00	7	14	275	147	40.1	39.6	39.9	0.8	0.93	0.767	1.03	0.354	0.149		Not Sand
11	16.7	18.0	8		19.7	0.79	1.00	1.00	1.00	1.00	6	13	302	160	37.0	36.2	36.6	0.8	0.91	0.727	1.03	0.340	0.136		Not Sand
12	18.2	18.0	5	92	21.2	0.75	1.00	1.00	1.00	1.00	4	10	329	172	28.6	26.1	27.3	0.8	0.90	0.687	1.03	0.325	0.109		Not Sand
13	19.7	18.0	6		22.7	0.72	1.00	1.00	1.00	1.00	4	10	356	184	30.7	28.7	29.7	0.8	0.88	0.647	1.03	0.309	0.115		Not Sand
14	21.2	18.0	7		24.2	0.69	1.00	1.00	1.00	1.00	5	11	383	197	32.5	30.9	31.7	0.8	0.87	0.607	1.03	0.293	0.121		Not Sand

Table C.17: Borehole A17 - Liquefaction resistance calculations according to Youd et al. (2001) SPT procedure.

SPT Equipment Parameters		
Energy efficiency	=	60 %
Sampling method	=	Standard sampler
Borehole diameter	=	65-115 mm

Ground Motion Parameters		
Moment Magnitude, M_w	=	7.4
Peak Ground Acceleration, a_{max}	=	0.38 g

Ground Water Level =	2.5 m

Soil Properties					SPT Corrections						Corrected SPT		Intermediate Calculations												FS
SPT #	z (m)	γ (kN/m²)	N_m	FC	lr (m)	C_N	C_E	C_B	C_R	C_S	$(N_1)_{60}$	$(N_1)_{60,CS}$	σ (kN/m²)	σ' (kN/m²)	D_{r1}	D_{r2}	$D_{r,ave}$	f	$K_σ$	r_d	MSF	CSR	$CRR_{7.5}$	
1	1.7	18.0	6		4.7	1.46	1.00	1.00	0.85	1.00	7	14	31	31	40.2	39.7	39.9	0.8	1.00	0.987	1.03	0.244	0.149	Not Sand
2	3.7	18.0	22	76	6.7	1.26	1.00	1.00	0.95	1.00	26	37	67	55	75.6	75.3	75.4	0.7	1.00	0.972	1.03	0.293	(N1)60>30	Not Sand
3	4.7	18.3	22	12	7.7	1.20	1.00	1.00	0.95	1.00	25	27	85	63	73.8	73.7	73.8	0.7	1.00	0.964	1.03	0.321	0.351	Not Sand
4	6.2	18.5	21	14	9.2	1.12	1.00	1.00	0.95	1.00	22	25	113	76	69.7	69.8	69.7	0.7	1.00	0.952	1.03	0.348	0.298	Not Sand
5	7.7	18.0	7		10.7	1.05	1.00	1.00	1.00	1.00	7	14	140	89	40.1	39.5	39.8	0.8	1.00	0.941	1.03	0.367	0.149	Not Sand
6	9.2	18.0	4		12.2	1.00	1.00	1.00	1.00	1.00	4	10	167	101	29.4	27.1	28.3	0.8	1.00	0.928	1.03	0.379	0.111	Not Sand
7	10.7	18.0	6	87	13.7	0.94	1.00	1.00	1.00	1.00	6	12	194	113	35.1	34.0	34.5	0.8	0.98	0.888	1.03	0.376	0.129	Not Sand
8	12.2	18.0	5		15.2	0.90	1.00	1.00	1.00	1.00	4	10	221	126	31.2	29.3	30.3	0.8	0.96	0.848	1.03	0.369	0.116	Not Sand
9	13.7	18.0	4		16.7	0.85	1.00	1.00	1.00	1.00	3	9	248	138	27.2	24.3	25.8	0.8	0.94	0.808	1.03	0.359	0.105	Not Sand
10	15.2	18.0	4		18.2	0.81	1.00	1.00	1.00	1.00	3	9	275	150	26.6	23.5	25.1	0.8	0.92	0.767	1.03	0.347	0.104	Not Sand
11	16.7	18.0	6		19.7	0.78	1.00	1.00	1.00	1.00	5	11	302	162	31.9	30.1	31.0	0.8	0.91	0.727	1.03	0.334	0.119	Not Sand
12	18.2	18.0	5		21.2	0.75	1.00	1.00	1.00	1.00	4	9	329	175	28.5	25.9	27.2	0.8	0.89	0.687	1.03	0.320	0.109	Not Sand
13	19.7	18.0	30		22.7	0.72	1.00	1.00	1.00	1.00	22	31	356	187	68.4	68.4	68.4	0.7	0.83	0.647	1.03	0.305	(N1)60>30	Not Sand
14	21.2	18.0	34	92	24.2	0.69	1.00	1.00	1.00	1.00	23	33	383	199	71.4	71.4	71.4	0.7	0.81	0.607	1.03	0.288	(N1)60>30	Not Sand

Table C.18: Borehole A18 - Liquefaction resistance calculations according to Youd et al. (2001) SPT procedure.

SPT Equipment Parameters		
Energy efficiency	=	60 %
Sampling method	=	Standard sampler
Borehole diameter	=	65-115 mm

Ground Motion Parameters		
Moment Magnitude, M_w	=	7.4
Peak Ground Acceleration, a_{max}	=	0.38 g

Ground Water Level =	2.3 m

Soil Properties					**SPT Corrections**						**Corrected SPT**		**Intermediate Calculations**												**FS**
SPT #	**z (m)**	**γ (kN/m²)**	**N_m**	**FC**	**lr (m)**	**C_N**	**C_E**	**C_B**	**C_R**	**C_S**	**$(N_1)_{60}$**	**$(N_1)_{60,CS}$**	**σ (kN/m²)**	**σ' (kN/m²)**	**D_{r1}**	**D_{r2}**	**$D_{r,ave}$**	**f**	**$K_σ$**	**r_d**	**MSF**	**CSR**	**$CRR_{7.5}$**		
1	1.7	18.0	17		4.7	1.46	1.00	1.00	0.85	1.00	21	30	31	31	67.6	67.7	67.7	0.7	1.00	0.987	1.03	0.244	(N1)60>30		3.00
2	3.2	18.0	21	37	6.2	1.30	1.00	1.00	0.95	1.00	26	36	58	49	75.2	74.9	75.1	0.7	1.00	0.975	1.03	0.287	(N1)60>30		3.00
3	4.7	18.5	21	11	7.7	1.21	1.00	1.00	0.95	1.00	24	26	86	62	72.5	72.4	72.4	0.7	1.00	0.964	1.03	0.331	0.312		**0.98**
4	6.2	18.0	17		9.2	1.13	1.00	1.00	0.95	1.00	18	27	113	74	63.1	63.0	63.0	0.7	1.00	0.952	1.03	0.358	0.338		**0.98**
5	7.7	18.0	29		10.7	1.07	1.00	1.00	1.00	1.00	31	42	140	86	82.0	80.4	81.2	0.6	1.00	0.941	1.03	0.376	(N1)60>30		Not Sand
6	9.2	18.5	15	44	12.2	1.00	1.00	1.00	1.00	1.00	15	23	168	99	57.2	56.8	57.0	0.7	1.00	0.928	1.03	0.386	0.258		**0.69**
7	10.7	18.0	19		13.7	0.95	1.00	1.00	1.00	1.00	18	27	195	112	62.6	62.5	62.6	0.7	0.97	0.888	1.03	0.382	0.329		**0.86**
8	12.2	18.0	30		15.2	0.90	1.00	1.00	1.00	1.00	27	37	222	124	76.7	76.2	76.5	0.7	0.94	0.848	1.03	0.374	(N1)60>30		3.00
9	13.7	18.5	25	12	16.7	0.86	1.00	1.00	1.00	1.00	21	23	249	137	68.2	68.3	68.2	0.7	0.91	0.808	1.03	0.363	0.265		**0.69**
10	15.2	18.0	22		18.2	0.82	1.00	1.00	1.00	1.00	18	27	276	149	62.5	62.4	62.4	0.7	0.89	0.767	1.03	0.351	0.327		**0.85**
11	16.7	18.6	33	2	19.7	0.78	1.00	1.00	1.00	1.00	26	26	304	162	74.8	74.5	74.6	0.7	0.86	0.727	1.03	0.336	0.307		**0.81**
12	18.2	18.0	33		21.2	0.75	1.00	1.00	1.00	1.00	25	35	331	175	73.2	73.1	73.1	0.7	0.85	0.687	1.03	0.322	(N1)60>30		3.00
13	19.7	18.0	32		22.7	0.72	1.00	1.00	1.00	1.00	23	33	358	187	70.6	70.7	70.6	0.7	0.83	0.647	1.03	0.306	(N1)60>30		3.00
14	21.2	18.0	25		24.2	0.69	1.00	1.00	1.00	1.00	17	26	385	199	61.2	61.0	61.1	0.7	0.81	0.607	1.03	0.290	0.306		**0.89**
15	24.2	18.0	29		27.2	0.64	1.00	1.00	1.00	1.00	19	27	439	224	63.5	63.4	63.5	0.7	0.79	z>23m	1.03		0.346		Not Sand

Table C.19: Borehole A19 - Liquefaction resistance calculations according to Youd et al. (2001) SPT procedure.

SPT Equipment Parameters	
Energy efficiency =	60 %
Sampling method =	Standard sampler
Borehole diameter =	65-115 mm

Ground Motion Parameters	
Moment Magnitude, M_w =	7.4
Peak Ground Acceleration, a_{max} =	0.38 g

Ground Water Level =	2.4 m

Soil Properties					SPT Corrections						Corrected SPT		Intermediate Calculations												FS
SPT #	z (m)	γ (kN/m²)	N_m	FC	lr (m)	C_N	C_E	C_B	C_R	C_S	$(N_1)_{60}$	$(N_1)_{60,CS}$	σ (kN/m²)	σ' (kN/m²)	D_{r1}	D_{r2}	$D_{r,ave}$	f	$K_σ$	r_d	MSF	CSR	$CRR_{7.5}$		
1	1.7	18.0	18		4.7	1.46	1.00	1.00	0.85	1.00	22	32	31	31	69.6	69.7	69.6	0.7	1.00	0.987	1.03	0.244	(N1)60>30		Not Sand
2	3.2	18.0	25	90	6.2	1.30	1.00	1.00	0.95	1.00	31	42	58	49	81.9	80.3	81.1	0.6	1.00	0.975	1.03	0.283	(N1)60>30		Not Sand
3	4.7	18.5	36	25	7.7	1.21	1.00	1.00	0.95	1.00	41	50	86	62	90.0	90.0	90.0	0.6	1.00	0.964	1.03	0.327	(N1)60>30		3.00
4	6.2	18.5	38	5	9.2	1.13	1.00	1.00	0.95	1.00	41	41	114	75	90.0	90.0	90.0	0.6	1.00	0.952	1.03	0.354	(N1)60>30		3.00
5	7.7	18.0	26		10.7	1.06	1.00	1.00	1.00	1.00	28	38	141	88	77.4	76.8	77.1	0.7	1.00	0.941	1.03	0.372	(N1)60>30		Not Sand
6	9.2	18.0	15		12.2	1.00	1.00	1.00	1.00	1.00	15	23	168	100	57.1	56.7	56.9	0.7	1.00	0.928	1.03	0.384	0.257		Not Sand
7	10.7	18.0	20	88	13.7	0.95	1.00	1.00	1.00	1.00	19	28	195	112	64.2	64.1	64.1	0.7	0.97	0.888	1.03	0.380	0.360		Not Sand
8	12.2	18.0	21	93	15.2	0.90	1.00	1.00	1.00	1.00	19	28	222	125	64.1	64.0	64.0	0.7	0.94	0.848	1.03	0.372	0.358		Not Sand
9	13.7	18.0	23		16.7	0.86	1.00	1.00	1.00	1.00	20	29	249	137	65.4	65.4	65.4	0.7	0.91	0.808	1.03	0.362	0.394		Not Sand
10	15.2	18.0	23		18.2	0.82	1.00	1.00	1.00	1.00	19	28	276	149	63.9	63.8	63.9	0.7	0.89	0.767	1.03	0.350	0.355		Not Sand
11	16.7	18.0	24	79	19.7	0.78	1.00	1.00	1.00	1.00	19	28	303	161	63.9	63.8	63.8	0.7	0.87	0.727	1.03	0.337	0.353		Not Sand
12	18.2	18.0	27	93	21.2	0.75	1.00	1.00	1.00	1.00	20	29	330	174	66.3	66.3	66.3	0.7	0.85	0.687	1.03	0.322	0.423		Not Sand
13	19.7	18.0	26		22.7	0.72	1.00	1.00	1.00	1.00	19	27	357	186	63.7	63.7	63.7	0.7	0.83	0.647	1.03	0.306	0.351		Not Sand
14	21.2	18.0	29		24.2	0.69	1.00	1.00	1.00	1.00	20	29	384	198	66.0	66.0	66.0	0.7	0.81	0.607	1.03	0.290	0.413		Not Sand
15	24.2	18.0	33		27.2	0.64	1.00	1.00	1.00	1.00	21	30	438	223	67.8	67.9	67.9	0.7	0.79	z>23m	1.03		(N1)60>30		Not Sand

Table C.20: Borehole A20 - Liquefaction resistance calculations according to Youd et al. (2001) SPT procedure.

SPT Equipment Parameters	
Energy efficiency =	60 %
Sampling method =	Standard sampler
Borehole diameter =	65-115 mm

Ground Motion Parameters	
Moment Magnitude, M_w =	7.4
Peak Ground Acceleration, a_{max} =	0.38 g

Ground Water Level =	3.3 m

Soil Properties					SPT Corrections						Corrected SPT		Intermediate Calculations												FS
SPT #	z (m)	γ (kN/m²)	N_m	FC	lr (m)	C_N	C_E	C_B	C_R	C_S	$(N_1)_{60}$	$(N_1)_{60,CS}$	σ (kN/m²)	σ' (kN/m²)	D_{r1}	D_{r2}	$D_{r,ave}$	f	$K_σ$	r_d	MSF	CSR	$CRR_{7.5}$		
1	1.7	18.0	14		4.7	1.46	1.00	1.00	0.85	1.00	17	26	31	31	61.4	61.2	61.3	0.7	1.00	0.987	1.03	0.244	0.309		Not Sand
2	3.7	18.0	40	84	6.7	1.21	1.00	1.00	0.95	1.00	46	60	67	62	90.0	90.0	90.0	0.6	1.00	0.972	1.03	0.258	(N1)60>30		3.00
3	4.7	18.6	41	22	7.7	1.15	1.00	1.00	0.95	1.00	45	53	86	71	90.0	90.0	90.0	0.6	1.00	0.964	1.03	0.286	(N1)60>30		3.00
4	6.2	18.6	46	23	9.2	1.08	1.00	1.00	0.95	1.00	47	56	113	84	90.0	90.0	90.0	0.6	1.00	0.952	1.03	0.317	(N1)60>30		Not Sand
5	7.7	18.0	22		10.7	1.02	1.00	1.00	1.00	1.00	22	32	140	97	69.7	69.8	69.7	0.7	1.00	0.941	1.03	0.338	(N1)60>30		Not Sand
6	9.2	18.0	25	87	12.2	0.96	1.00	1.00	1.00	1.00	24	34	167	109	72.3	72.3	72.3	0.7	0.97	0.928	1.03	0.353	(N1)60>30		Not Sand
7	10.7	18.0	29		13.7	0.91	1.00	1.00	1.00	1.00	26	37	194	121	75.8	75.5	75.7	0.7	0.94	0.888	1.03	0.352	(N1)60>30		Not Sand
8	12.2	18.0	31		15.2	0.87	1.00	1.00	1.00	1.00	27	37	221	133	76.5	76.0	76.3	0.7	0.92	0.848	1.03	0.347	(N1)60>30		Not Sand
9	13.7	18.0	28		16.7	0.83	1.00	1.00	1.00	1.00	23	33	248	146	71.0	71.0	71.0	0.7	0.89	0.808	1.03	0.340	(N1)60>30		Not Sand
10	15.2	18.0	29		18.2	0.79	1.00	1.00	1.00	1.00	23	33	275	158	70.6	70.7	70.7	0.7	0.87	0.767	1.03	0.331	(N1)60>30		Not Sand
11	16.7	18.0	25		19.7	0.76	1.00	1.00	1.00	1.00	19	28	302	170	64.2	64.1	64.1	0.7	0.85	0.727	1.03	0.319	0.361		Not Sand
12	18.2	18.0	32	93	21.2	0.73	1.00	1.00	1.00	1.00	23	33	329	183	71.1	71.2	71.1	0.7	0.83	0.687	1.03	0.306	(N1)60>30		Not Sand
13	19.7	18.0	41		22.7	0.70	1.00	1.00	1.00	1.00	29	39	356	195	78.9	78.0	78.5	0.7	0.82	0.647	1.03	0.293	(N1)60>30		Not Sand
14	21.2	18.0	43		24.2	0.67	1.00	1.00	1.00	1.00	29	40	383	207	79.3	78.3	78.8	0.7	0.80	0.607	1.03	0.278	(N1)60>30		Not Sand
15	24.2	18.0	49	93	27.2	0.63	1.00	1.00	1.00	1.00	31	42	437	232	81.6	80.2	80.9	0.6	0.71	z>23m	1.03		(N1)60>30		Not Sand

Table C.21: Borehole F1 - Liquefaction resistance calculations according to Youd et al. (2001) SPT procedure.

SPT Equipment Parameters	
Energy efficiency =	45 %
Sampling method =	Standard sampler
Borehole diameter =	65-115 mm

Ground Motion Parameters	
Moment Magnitude, M_w =	7.4
Peak Ground Acceleration, a_{max} =	0.38 g

Ground Water Level =	2.0 m

Soil Properties					SPT Corrections						Corrected SPT		Intermediate Calculations											FS
SPT #	z (m)	γ (kN/m²)	N_m	FC	lr (m)	C_N	C_E	C_B	C_R	C_S	$(N_1)_{60}$	$(N_1)_{60,CS}$	σ (kN/m²)	σ' (kN/m²)	D_{r1}	D_{r2}	$D_{r,ave}$	f	$K_σ$	r_d	MSF	CSR	$CRR_{7.5}$	FS
1	2.0	18.0	10	20	5.0	1.41	0.75	1.00	0.85	1.00	9	13	36	36	44.2	43.9	44.0	0.7	1.00	0.985	1.03	0.243	0.144	3.00
2	3.5	18.0	26	8	6.5	1.31	0.75	1.00	0.95	1.00	24	25	63	48	72.6	72.5	72.5	0.7	1.00	0.973	1.03	0.314	0.288	**0.95**
3	5.0	18.0	33	8	8.0	1.22	0.75	1.00	0.95	1.00	29	29	90	61	78.9	78.0	78.5	0.7	1.00	0.962	1.03	0.353	0.426	1.25
4	6.5	18.0	19	45	9.5	1.14	0.75	1.00	0.95	1.00	15	24	117	73	57.9	57.6	57.8	0.7	1.00	0.950	1.03	0.377	0.265	**0.73**
5	8.0	18.0	14		11.0	1.07	0.75	1.00	1.00	1.00	11	19	144	85	49.5	49.1	49.3	0.7	1.00	0.939	1.03	0.392	0.198	Not Sand
6	9.5	18.0	26		12.5	1.01	0.75	1.00	1.00	1.00	20	20	171	97	65.5	65.5	65.5	0.7	1.00	0.920	1.03	0.399	0.212	Not Sand
7	11.0	18.0	31		14.0	0.96	0.75	1.00	1.00	1.00	22	32	198	110	69.6	69.6	69.6	0.7	0.97	0.880	1.03	0.392	(N1)60>30	Not Sand
8	12.5	18.0	32		15.5	0.91	0.75	1.00	1.00	1.00	22	31	225	122	68.9	68.9	68.9	0.7	0.94	0.840	1.03	0.383	(N1)60>30	Not Sand
9	14.0	18.0	37		17.0	0.87	0.75	1.00	1.00	1.00	24	34	252	134	72.2	72.2	72.2	0.7	0.92	0.800	1.03	0.371	(N1)60>30	Not Sand
10	15.5	18.0	41		18.5	0.83	0.75	1.00	1.00	1.00	25	35	279	147	74.3	74.1	74.2	0.7	0.89	0.760	1.03	0.357	(N1)60>30	Not Sand

Table C.22: Borehole F2 - Liquefaction resistance calculations according to Youd et al. (2001) SPT procedure.

SPT Equipment Parameters		
Energy efficiency	=	45 %
Sampling method	=	Standard sampler
Borehole diameter	=	65-115 mm

Ground Motion Parameters		
Moment Magnitude, M_w	=	7.4
Peak Ground Acceleration, a_{max}	=	0.38 g

Ground Water Level =	2.7 m

Soil Properties					SPT Corrections						Corrected SPT		Intermediate Calculations												FS
SPT #	z (m)	γ (kN/m²)	N_m	FC	lr (m)	C_N	C_E	C_B	C_R	C_S	$(N_1)_{60}$	$(N_1)_{60,CS}$	σ (kN/m²)	σ' (kN/m²)	D_{r1}	D_{r2}	$D_{r,ave}$	f	$K_σ$	r_d	MSF	CSR	$CRR_{7.5}$		
1	1.5	18.0	17		4.5	1.50	0.75	1.00	0.85	1.00	16	16	27	27	59.4	59.1	59.2	0.7	1.00	0.989	1.03	0.244	0.173		Not Sand
2	3.5	18.0	32	10	4.5	1.26	0.75	1.00	0.85	1.00	26	27	63	55	74.6	74.4	74.5	0.7	1.00	0.973	1.03	0.275	0.340		1.28
3	5.0	18.0	30	10	6.5	1.17	0.75	1.00	0.95	1.00	25	27	90	67	73.9	73.7	73.8	0.7	1.00	0.962	1.03	0.317	0.325		1.06
4	6.5	18.0	16		8.0	1.10	0.75	1.00	0.95	1.00	13	13	117	80	52.2	51.9	52.0	0.7	1.00	0.950	1.03	0.344	0.136		Not Sand
5	8.0	18.0	32		9.5	1.04	0.75	1.00	0.95	1.00	24	24	144	92	71.7	71.7	71.7	0.7	1.00	0.939	1.03	0.363	0.268		Not Sand
6	9.5	18.0	37		11.0	0.98	0.75	1.00	1.00	1.00	27	27	171	104	76.9	76.4	76.7	0.7	0.99	0.920	1.03	0.373	0.345		Not Sand
7	11.0	18.0	50		12.5	0.93	0.75	1.00	1.00	1.00	35	35	198	117	87.1	84.4	85.7	0.6	0.94	0.880	1.03	0.369	$(N1)_{60}$>30		Not Sand

Table C.23: Borehole F3 - Liquefaction resistance calculations according to Youd et al. (2001) SPT procedure.

SPT Equipment Parameters		
Energy efficiency	=	45 %
Sampling method	=	Standard sampler
Borehole diameter	=	65-115 mm

Ground Motion Parameters		
Moment Magnitude, M_w	=	7.4
Peak Ground Acceleration, a_{max}	=	0.38 g

Ground Water Level =	2.3 m

Soil Properties					**SPT Corrections**						**Corrected SPT**		**Intermediate Calculations**											**FS**
SPT #	**z (m)**	**γ (kN/m²)**	**N_m**	**FC**	**lr (m)**	**C_N**	**C_E**	**C_B**	**C_R**	**C_S**	**$(N_1)_{60}$**	**$(N_1)_{60,CS}$**	**σ (kN/m²)**	**σ' (kN/m²)**	**D_{r1}**	**D_{r2}**	**$D_{r,ave}$**	**f**	**$K_σ$**	**r_d**	**MSF**	**CSR**	**$CRR_{7.5}$**	
1	2.0	18.0	8	10	5.0	1.41	0.75	1.00	0.85	1.00	7	8	36	36	39.5	39.0	39.3	0.8	1.00	0.985	1.03	0.243	0.098	3.00
2	3.5	18.0	13	10	6.5	1.28	0.75	1.00	0.95	1.00	12	13	63	51	50.9	50.5	50.7	0.7	1.00	0.973	1.03	0.296	0.141	**0.49**
3	5.0	18.0	27	10	8.0	1.20	0.75	1.00	0.95	1.00	23	24	90	64	70.8	70.9	70.8	0.7	1.00	0.962	1.03	0.337	0.281	**0.86**
4	6.5	18.0	38	10	9.5	1.12	0.75	1.00	0.95	1.00	30	32	117	76	81.3	79.9	80.6	0.6	1.00	0.950	1.03	0.362	(N1)60>30	3.00
5	8.0	18.0	38		11.0	1.06	0.75	1.00	1.00	1.00	30	41	144	88	80.9	79.6	80.3	0.6	1.00	0.939	1.03	0.379	(N1)60>30	Not Sand
6	9.5	18.0	41		12.5	1.00	0.75	1.00	1.00	1.00	31	31	171	100	81.7	80.2	81.0	0.6	1.00	0.920	1.03	0.387	(N1)60>30	Not Sand
7	11.0	18.0	45		14.0	0.95	0.75	1.00	1.00	1.00	32	43	198	113	83.3	81.4	82.4	0.6	0.95	0.880	1.03	0.382	(N1)60>30	Not Sand
8	12.5	18.0	47		15.5	0.90	0.75	1.00	1.00	1.00	32	43	225	125	83.0	81.2	82.1	0.6	0.91	0.840	1.03	0.374	(N1)60>30	Not Sand
9	14.0	18.0	49		17.0	0.86	0.75	1.00	1.00	1.00	31	43	252	137	82.7	81.0	81.8	0.6	0.88	0.800	1.03	0.363	(N1)60>30	Not Sand
10	15.5	18.0	50		18.5	0.82	0.75	1.00	1.00	1.00	31	42	279	150	81.6	80.1	80.8	0.6	0.85	0.760	1.03	0.350	(N1)60>30	Not Sand

Table C.24: Borehole F4 - Liquefaction resistance calculations according to Youd et al. (2001) SPT procedure.

SPT Equipment Parameters		
Energy efficiency	=	45 %
Sampling method	=	Standard sampler
Borehole diameter	=	65-115 mm

Ground Motion Parameters		
Moment Magnitude, M_w	=	7.4
Peak Ground Acceleration, a_{max}	=	0.38 g

Ground Water Level =	2.0 m

Soil Properties					SPT Corrections						Corrected SPT		Intermediate Calculations											FS
SPT #	z (m)	γ (kN/m²)	N_m	FC	lr (m)	C_N	C_E	C_B	C_R	C_S	$(N_1)_{60}$	$(N_1)_{60,CS}$	σ (kN/m²)	σ' (kN/m²)	D_{r1}	D_{r2}	$D_{r,ave}$	f	$K_σ$	r_d	MSF	CSR	$CRR_{7.5}$	
1	2.0	18.0	10	57	5.0	1.41	0.75	1.00	0.85	1.00	9	16	36	36	44.2	43.9	44.0	0.7	1.00	0.985	1.03	0.243	0.168	Not Sand
2	3.5	18.0	13	27	6.5	1.31	0.75	1.00	0.95	1.00	12	18	63	48	51.3	50.9	51.1	0.7	1.00	0.973	1.03	0.314	0.194	**0.64**
3	5.0	18.0	17	27	8.0	1.22	0.75	1.00	0.95	1.00	15	21	90	61	56.6	56.3	56.5	0.7	1.00	0.962	1.03	0.353	0.230	**0.68**
4	6.5	18.0	10		9.5	1.14	0.75	1.00	0.95	1.00	8	8	117	73	42.0	41.6	41.8	0.7	1.00	0.950	1.03	0.377	0.097	Not Sand
5	8.0	18.0	12		11.0	1.07	0.75	1.00	1.00	1.00	10	17	144	85	45.8	45.5	45.6	0.7	1.00	0.939	1.03	0.392	0.176	Not Sand
6	9.5	18.0	21		12.5	1.01	0.75	1.00	1.00	1.00	16	16	171	97	58.9	58.6	58.7	0.7	1.00	0.920	1.03	0.399	0.170	Not Sand
7	11.0	18.0	47		14.0	0.96	0.75	1.00	1.00	1.00	34	46	198	110	85.7	83.3	84.5	0.6	0.96	0.880	1.03	0.392	(N1)60>30	Not Sand
8	12.5	18.0	48		15.5	0.91	0.75	1.00	1.00	1.00	33	44	225	122	84.3	82.3	83.3	0.6	0.92	0.840	1.03	0.383	(N1)60>30	Not Sand
9	14.0	18.0	R		17.0	0.87	0.75	1.00	1.00	1.00	R	R	252	134	90.0	90.0	90.0	0.6	0.89	0.800	1.03	0.371	(N1)60>30	Not Sand
10	15.5	18.0	R		18.5	0.83	0.75	1.00	1.00	1.00	R	R	279	147	90.0	90.0	90.0	0.6	0.86	0.760	1.03	0.357	(N1)60>30	Not Sand

Table C.25: Borehole F5 - Liquefaction resistance calculations according to Youd et al. (2001) SPT procedure.

SPT Equipment Parameters		
Energy efficiency	=	45 %
Sampling method	=	Standard sampler
Borehole diameter	=	65-115 mm

Ground Motion Parameters		
Moment Magnitude, M_w	=	7.4
Peak Ground Acceleration, a_{max}	=	0.38 g

Ground Water Level =	1.4 m

Soil Properties					**SPT Corrections**						**Corrected SPT**		**Intermediate Calculations**											**FS**
SPT #	**z (m)**	**γ (kN/m²)**	**N_m**	**FC**	**lr (m)**	**C_N**	**C_E**	**C_B**	**C_R**	**C_S**	**$(N_1)_{60}$**	**$(N_1)_{60,CS}$**	**σ (kN/m²)**	**σ' (kN/m²)**	**D_{r1}**	**D_{r2}**	**$D_{r,ave}$**	**f**	**$K_σ$**	**r_d**	**MSF**	**CSR**	**$CRR_{7.5}$**	
1	2.0	18.0	11	20	5.0	1.47	0.75	1.00	0.85	1.00	10	15	36	30	47.3	46.9	47.1	0.7	1.00	0.985	1.03	0.291	0.157	**0.56**
2	3.5	18.0	21	20	6.5	1.35	0.75	1.00	0.95	1.00	20	25	63	42	66.4	66.4	66.4	0.7	1.00	0.973	1.03	0.357	0.302	**0.87**
3	5.0	18.0	15	20	8.0	1.26	0.75	1.00	0.95	1.00	13	18	90	55	54.1	53.7	53.9	0.7	1.00	0.962	1.03	0.391	0.193	Not Sand
4	6.5	18.0	28	20	9.5	1.18	0.75	1.00	0.95	1.00	23	29	117	67	71.4	71.5	71.5	0.7	1.00	0.950	1.03	0.410	0.408	1.03
5	8.0	18.0	28		11.0	1.10	0.75	1.00	1.00	1.00	23	33	144	79	71.0	71.0	71.0	0.7	1.00	0.939	1.03	0.421	(N1)60>30	Not Sand
6	9.5	18.0	38		12.5	1.04	0.75	1.00	1.00	1.00	30	30	171	92	80.3	79.1	79.7	0.7	1.00	0.920	1.03	0.425	0.444	Not Sand
7	11.0	18.0	40		14.0	0.98	0.75	1.00	1.00	1.00	29	40	198	104	80.1	78.9	79.5	0.7	0.99	0.880	1.03	0.415	(N1)60>30	Not Sand
8	12.5	18.0	47		15.5	0.93	0.75	1.00	1.00	1.00	33	44	225	116	84.5	82.4	83.4	0.6	0.94	0.840	1.03	0.402	(N1)60>30	Not Sand
9	14.0	18.0	47		17.0	0.89	0.75	1.00	1.00	1.00	31	42	252	128	82.4	80.7	81.6	0.6	0.90	0.800	1.03	0.388	(N1)60>30	Not Sand
10	15.5	18.0	49		18.5	0.84	0.75	1.00	1.00	1.00	31	42	279	141	82.1	80.5	81.3	0.6	0.87	0.760	1.03	0.372	(N1)60>30	Not Sand
11	16.7	18.0	25		19.7	0.81	0.75	1.00	1.00	1.00	15	23	301	151	57.6	57.2	57.4	0.7	0.88	0.727	1.03	0.359	0.261	Not Sand

Note: Fines content values are assumed.

Table C.26: Borehole F6 - Liquefaction resistance calculations according to Youd et al. (2001) SPT procedure.

SPT Equipment Parameters		
Energy efficiency	=	45 %
Sampling method	=	Standard sampler
Borehole diameter	=	65-115 mm

Ground Motion Parameters		
Moment Magnitude, M_w	=	7.4
Peak Ground Acceleration, a_{max}	=	0.38 g

Ground Water Level =	2.6 m

Soil Properties					SPT Corrections						Corrected SPT		Intermediate Calculations												FS
SPT #	z (m)	γ (kN/m²)	N_m	FC	lr (m)	C_N	C_E	C_B	C_R	C_S	$(N_1)_{60}$	$(N_1)_{60,CS}$	σ (kN/m²)	σ' (kN/m²)	D_{r1}	D_{r2}	$D_{r,ave}$	f	K_σ	r_d	MSF	CSR	$CRR_{7.5}$		
1	2.0	18.0	14	81	5.0	1.41	0.75	1.00	0.85	1.00	13	20	36	36	52.3	51.9	52.1	0.7	1.00	0.985	1.03	0.243	0.217		Not Sand
2	3.5	18.0	22	14	6.5	1.26	0.75	1.00	0.95	1.00	20	23	63	54	65.6	65.6	65.6	0.7	1.00	0.973	1.03	0.280	0.255		Not Sand
3	5.0	18.0	31	20	8.0	1.18	0.75	1.00	0.95	1.00	26	32	90	66	75.3	75.0	75.1	0.7	1.00	0.962	1.03	0.322	(N1)60>30		3.00
4	6.5	18.0	13	20	9.5	1.11	0.75	1.00	0.95	1.00	10	15	117	79	47.2	46.9	47.0	0.7	1.00	0.950	1.03	0.349	0.157		Not Sand
5	8.0	18.0	26		11.0	1.04	0.75	1.00	1.00	1.00	20	29	144	91	66.5	66.5	66.5	0.7	1.00	0.939	1.03	0.367	0.430		Not Sand
6	9.5	18.0	36		12.5	0.99	0.75	1.00	1.00	1.00	27	27	171	103	76.0	75.7	75.9	0.7	0.99	0.920	1.03	0.376	0.328		Not Sand
7	11.0	18.0	39		14.0	0.93	0.75	1.00	1.00	1.00	27	38	198	116	77.1	76.5	76.8	0.7	0.96	0.880	1.03	0.372	(N1)60>30		Not Sand
8	12.5	18.0	44		15.5	0.89	0.75	1.00	1.00	1.00	29	40	225	128	79.8	78.7	79.3	0.7	0.93	0.840	1.03	0.365	(N1)60>30		Not Sand
9	14.0	18.0	42		17.0	0.85	0.75	1.00	1.00	1.00	27	37	252	140	76.1	75.7	75.9	0.7	0.90	0.800	1.03	0.355	(N1)60>30		Not Sand
10	15.5	18.0	45		18.5	0.81	0.75	1.00	1.00	1.00	27	38	279	152	77.0	76.4	76.7	0.7	0.88	0.760	1.03	0.344	(N1)60>30		Not Sand

Table C.27: Borehole F7 - Liquefaction resistance calculations according to Youd et al. (2001) SPT procedure.

SPT Equipment Parameters		
Energy efficiency	=	45 %
Sampling method	=	Standard sampler
Borehole diameter	=	65-115 mm

Ground Motion Parameters		
Moment Magnitude, M_w	=	7.4
Peak Ground Acceleration, a_{max}	=	0.38 g

Assumed Ground Water Level =	1.0 m

Soil Properties					SPT Corrections						Corrected SPT		Intermediate Calculations												
SPT #	**z (m)**	**γ (kN/m²)**	**N_m**	**FC**	**lr (m)**	**C_N**	**C_E**	**C_B**	**C_R**	**C_S**	**$(N_1)_{60}$**	**$(N_1)_{60,CS}$**	**σ (kN/m²)**	**σ' (kN/m²)**	**D_{r1}**	**D_{r2}**	**$D_{r,ave}$**	**f**	**$K_σ$**	**r_d**	**MSF**	**CSR**	**$CRR_{7.5}$**	**FS**
1	2.0	18.0	7		5.0	1.50	0.75	1.00	0.85	1.00	7	7	36	26	38.2	37.5	37.9	0.8	1.00	0.985	1.03	0.334	0.085	Not Sand
2	3.5	18.0	24	16	6.5	1.39	0.75	1.00	0.95	1.00	24	28	63	38	71.8	71.9	71.8	0.7	1.00	0.973	1.03	0.394	0.362	**0.95**
3	5.0	18.0	21	16	8.0	1.29	0.75	1.00	0.95	1.00	19	23	90	51	64.7	64.7	64.7	0.7	1.00	0.962	1.03	0.421	0.258	**0.63**
4	6.5	18.0	20	16	9.5	1.20	0.75	1.00	0.95	1.00	17	21	117	63	61.0	60.8	60.9	0.7	1.00	0.950	1.03	0.436	0.226	**0.54**
5	8.0	18.0	18	16	11.0	1.13	0.75	1.00	1.00	1.00	15	19	144	75	57.5	57.1	57.3	0.7	1.00	0.939	1.03	0.443	0.201	**0.47**
6	9.5	18.0	22		12.5	1.06	0.75	1.00	1.00	1.00	17	17	171	88	61.7	61.5	61.6	0.7	1.00	0.920	1.03	0.444	0.186	Not Sand
7	11.0	18.0	49		14.0	1.00	0.75	1.00	1.00	1.00	37	49	198	100	89.4	86.4	87.9	0.6	1.00	0.880	1.03	0.431	(N1)60>30	Not Sand
8	12.5	18.0	R		15.5	0.95	0.75	1.00	1.00	1.00	R	R	225	112	90.0	90.0	90.0	0.6	0.96	0.840	1.03	0.416	(N1)60>30	Not Sand
9	14.0	18.0	R		17.0	0.90	0.75	1.00	1.00	1.00	R	R	252	124	90.0	90.0	90.0	0.6	0.92	0.800	1.03	0.400	(N1)60>30	Not Sand
10	15.5	18.0	R		18.5	0.86	0.75	1.00	1.00	1.00	R	R	279	137	90.0	90.0	90.0	0.6	0.88	0.760	1.03	0.383	(N1)60>30	Not Sand

APPENDIX D

TIME HISTORIES OF USED
GROUND MOTION RECORS

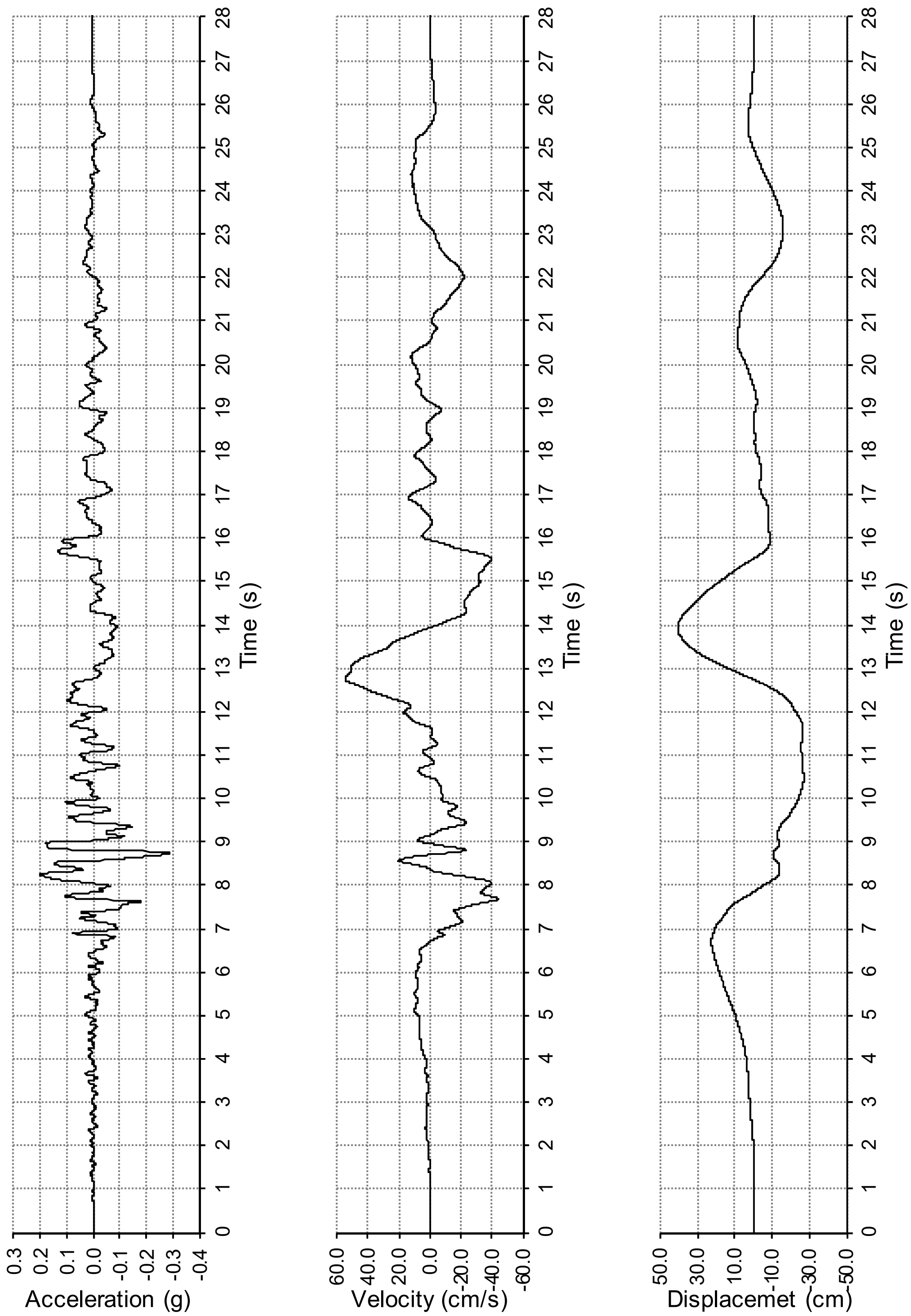

Figure D.1: Scaled İzmit record NS component acceleration, velocity displacement histories used in the response analyses (Scale factor = 0.925).

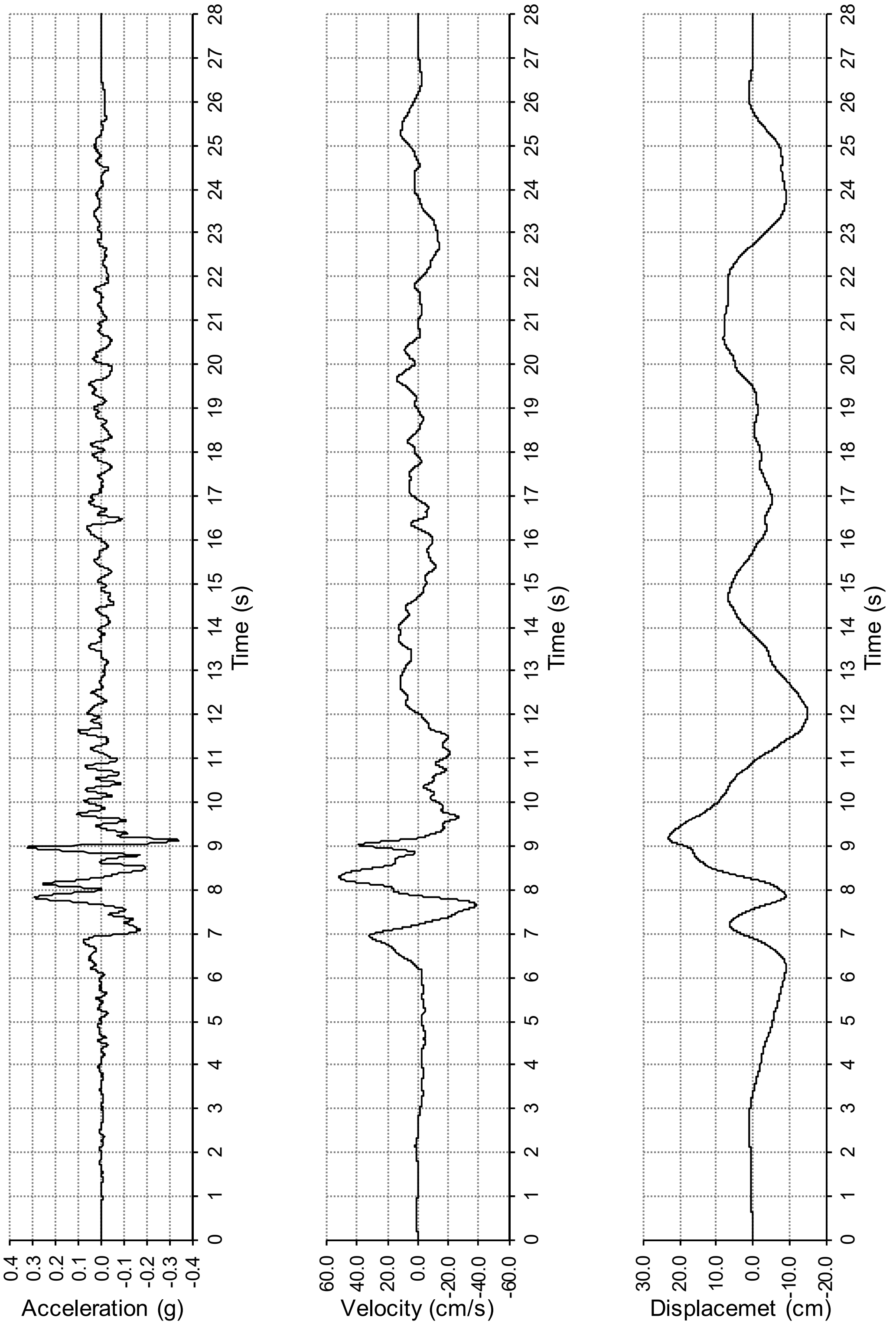

Figure D.2: Scaled İzmit record EW component acceleration, velocity displacement histories used in the response analyses (Scale factor = 0.925).

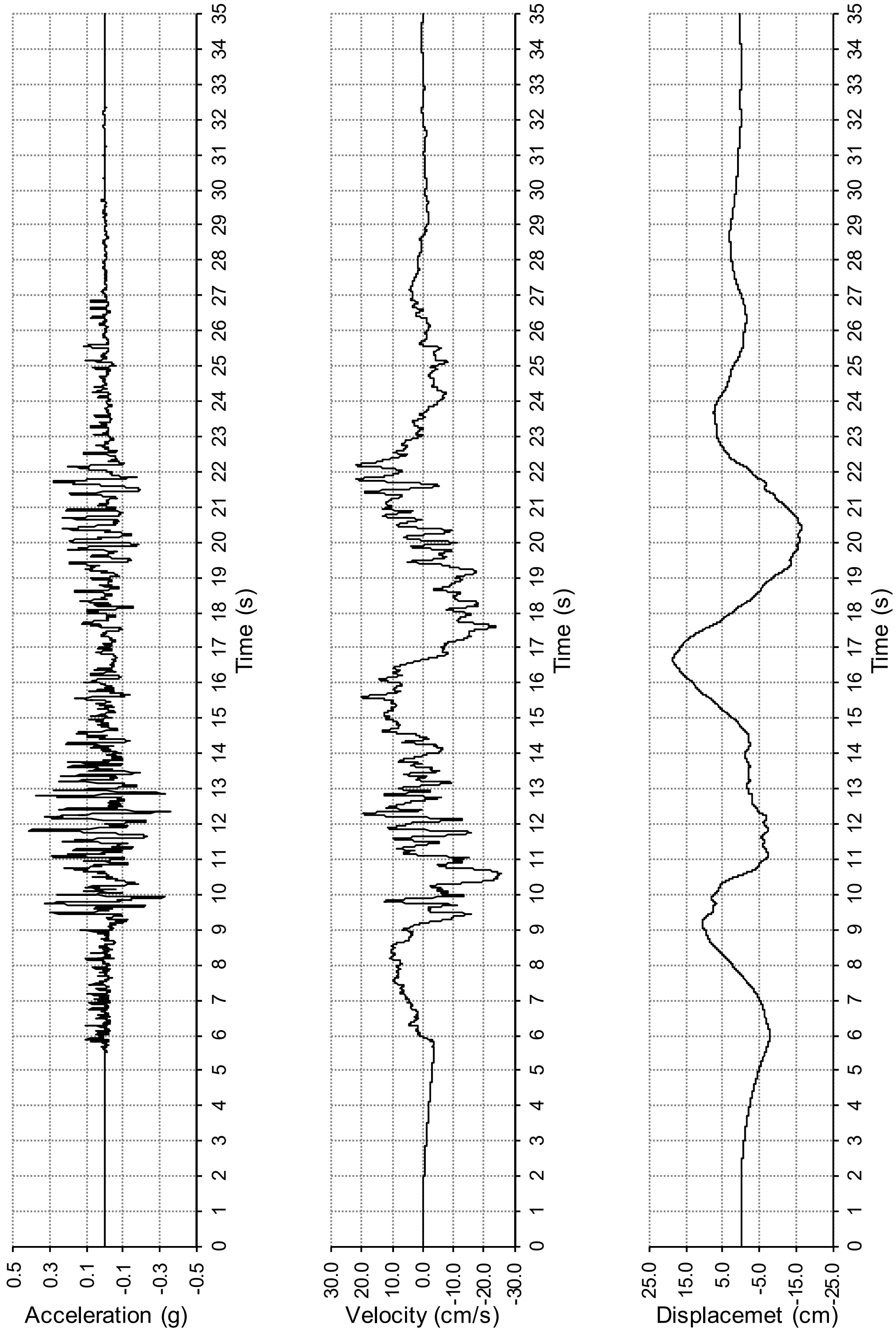

Figure D.3: Scaled Düzce record NS component acceleration, velocity displacement histories used in the response analyses (Scale factor = 1.046).

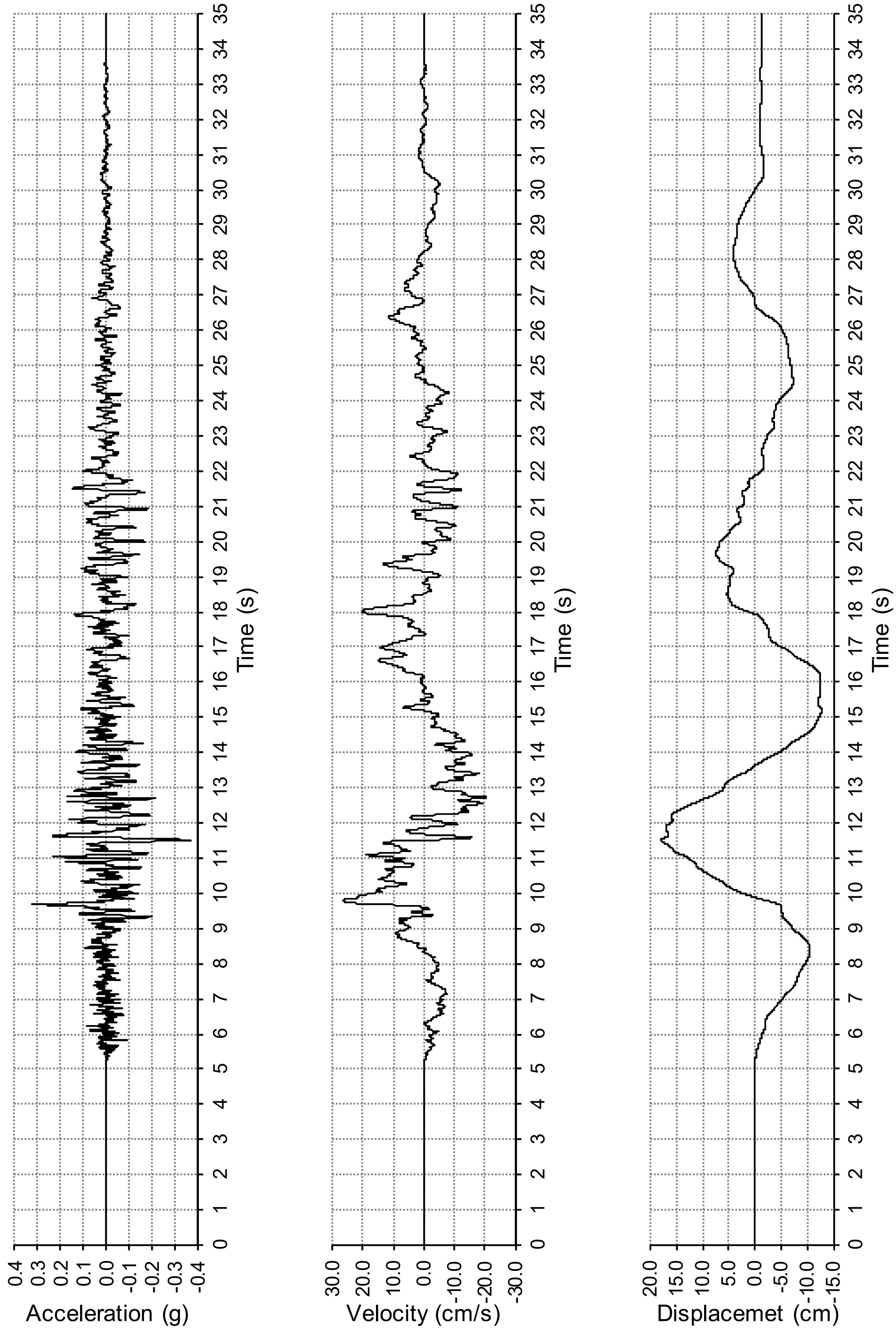

Figure D.4: Scaled Düzce record NS component acceleration, velocity displacement histories used in the response analyses (Scale factor = 1.046).

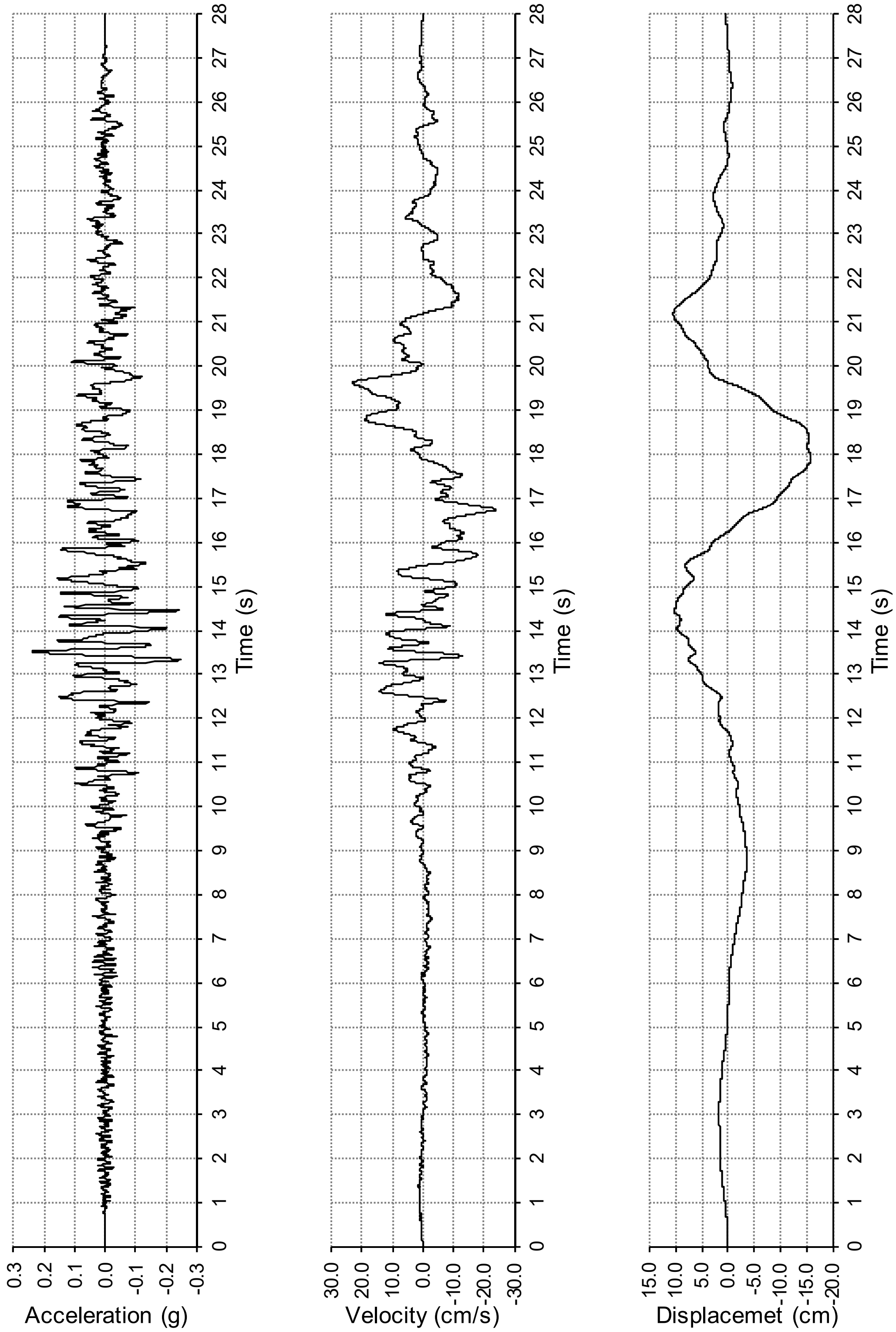

Figure D.5: Scaled Landers record LN component acceleration, velocity displacement histories used in the response analyses (Scale factor = 0.87).

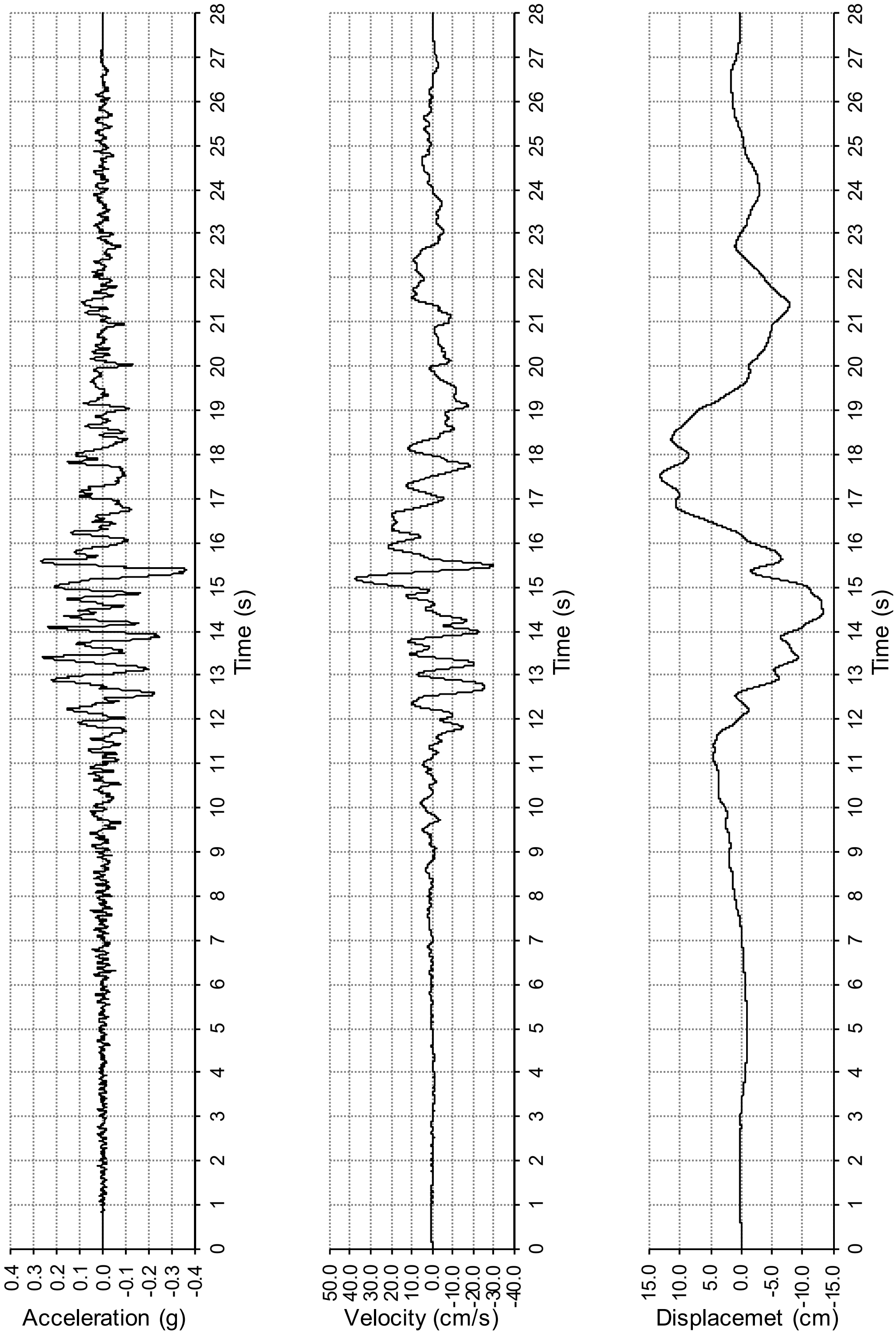

Figure D.6: Scaled Landers record TR component acceleration, velocity displacement histories used in the response analyses (Scale factor = 0.87).

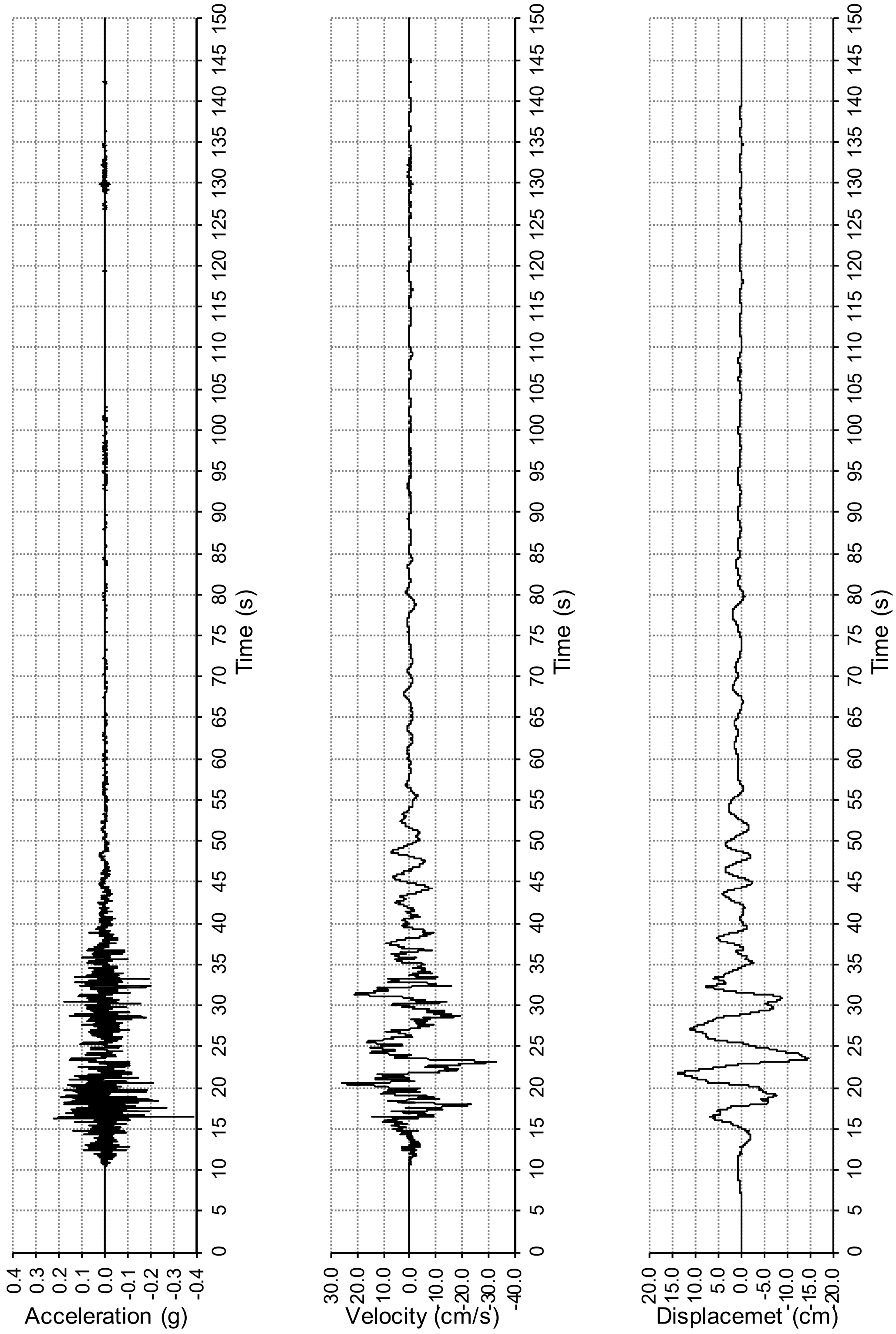

Figure D.7: Scaled Darfield record 17° component acceleration, velocity displacement histories used in the response analyses (Scale factor = 0.824).

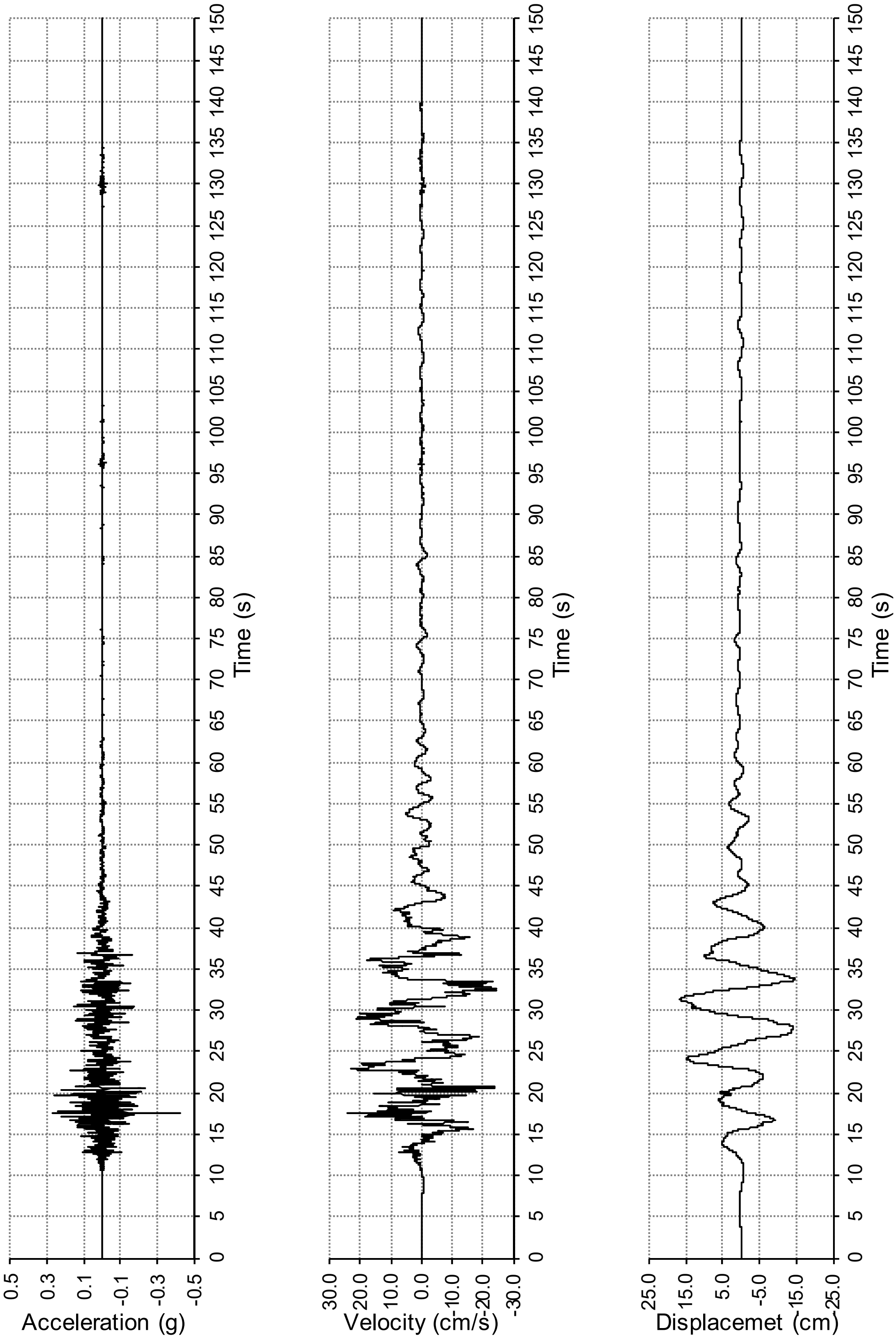

Figure D.8: Scaled Darfield record 73° component acceleration, velocity displacement histories used in the response analyses (Scale factor = 0.824).

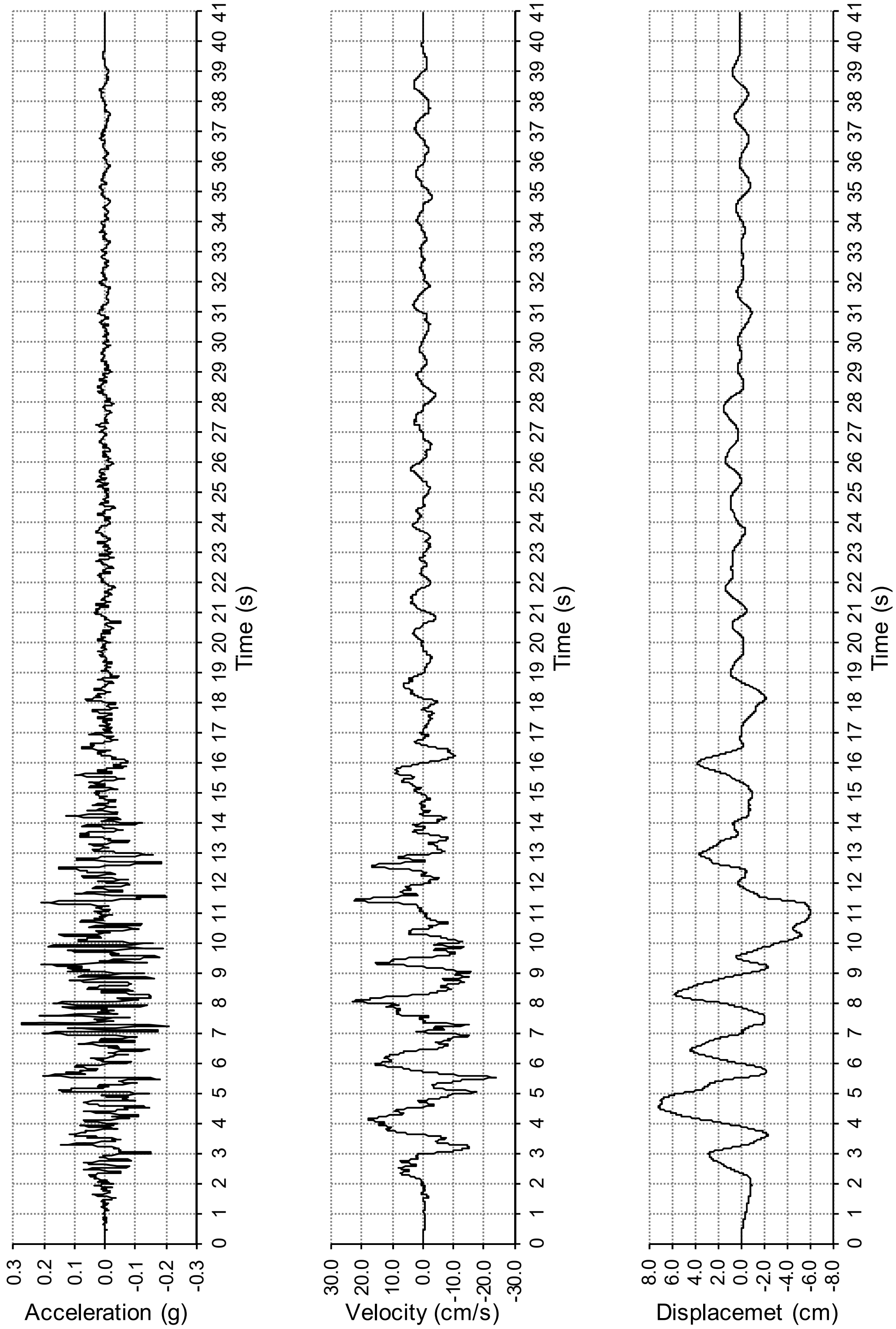

Figure D.9: Scaled Kobe record 0º component acceleration, velocity displacement histories used in the response analyses (Scale factor = 1.141).

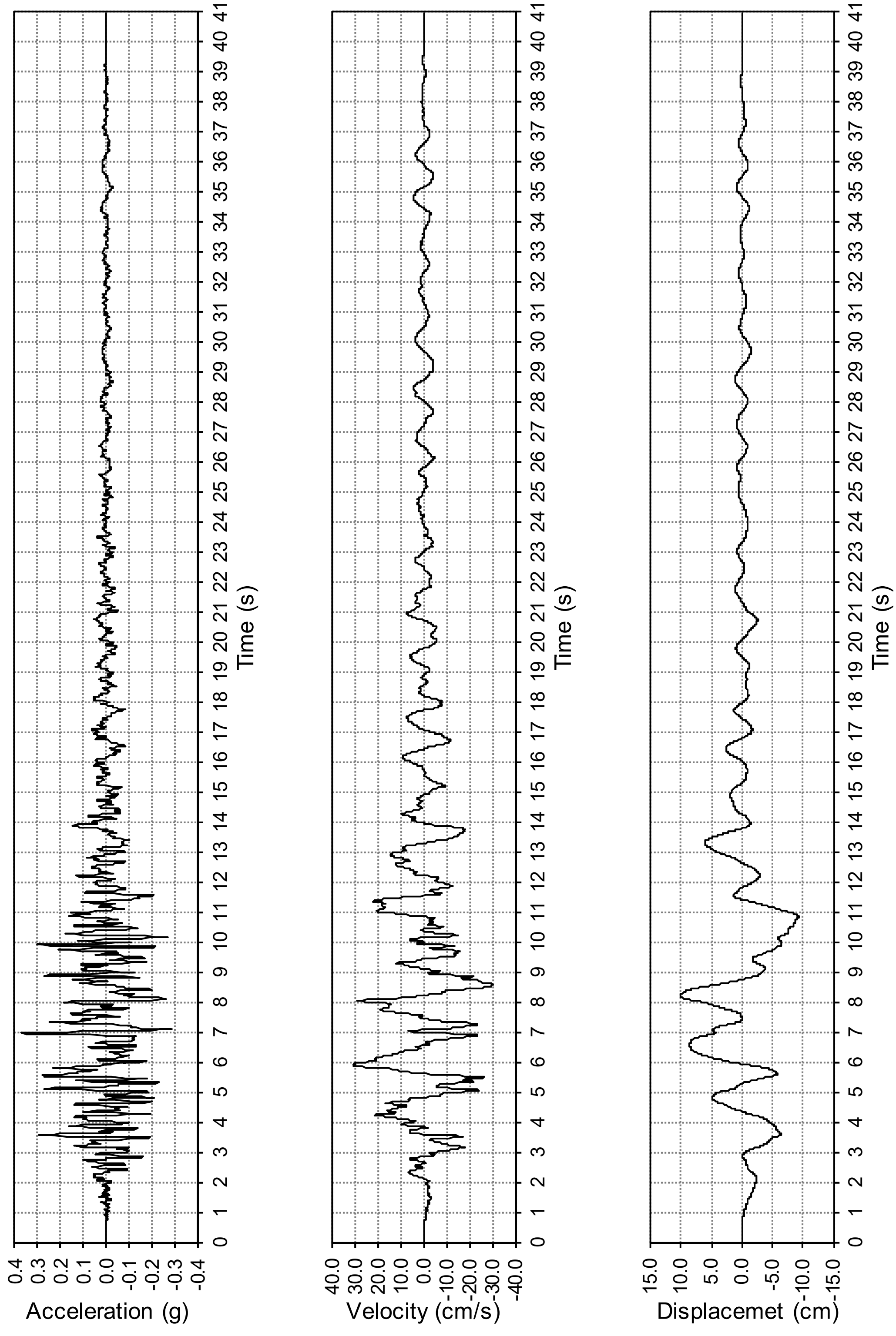

Figure D.10: Scaled Kobe record 90º component acceleration, velocity displacement histories used in the response analyses (Scale factor = 1.141).

APPENDIX E

THE REST OF SITE RESPONSE ANALYSES RESULTS

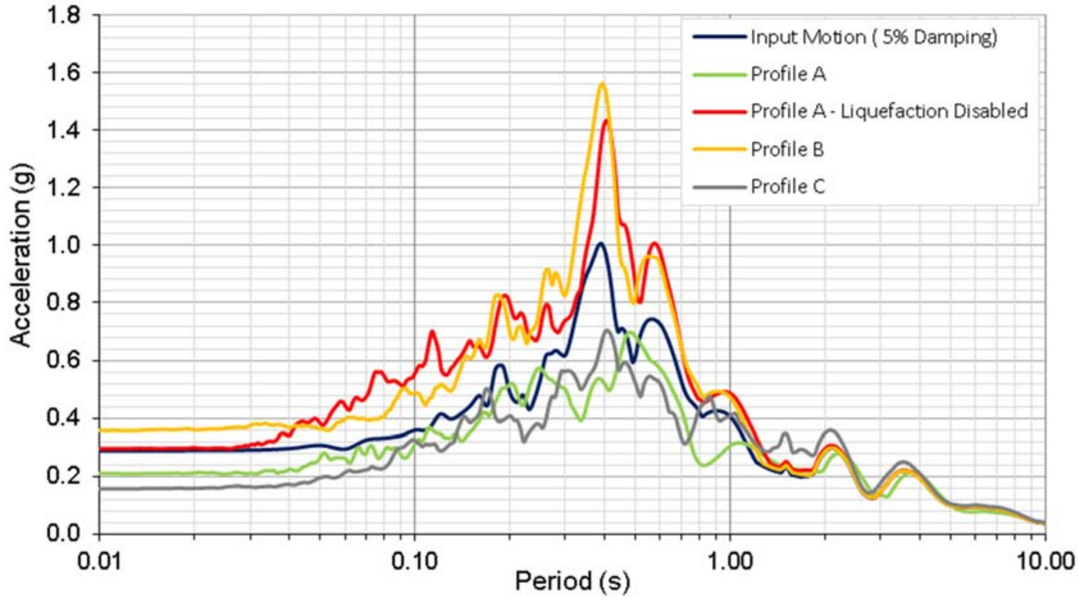

Figure E.1: İzmit records' NS component acceleration response spectra.

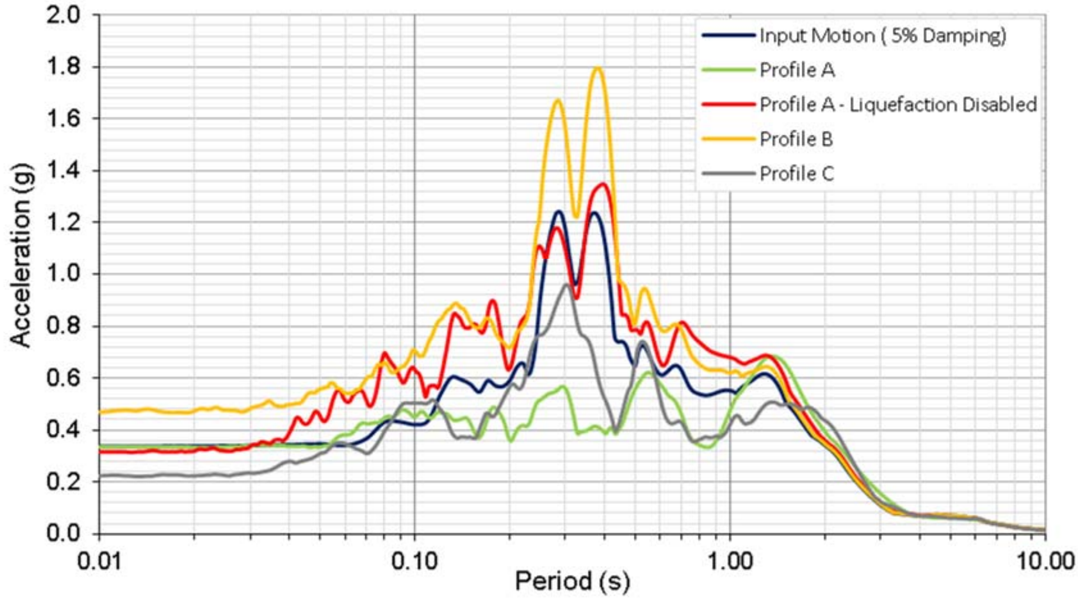

Figure E.2: İzmit records' EW component acceleration response spectra.

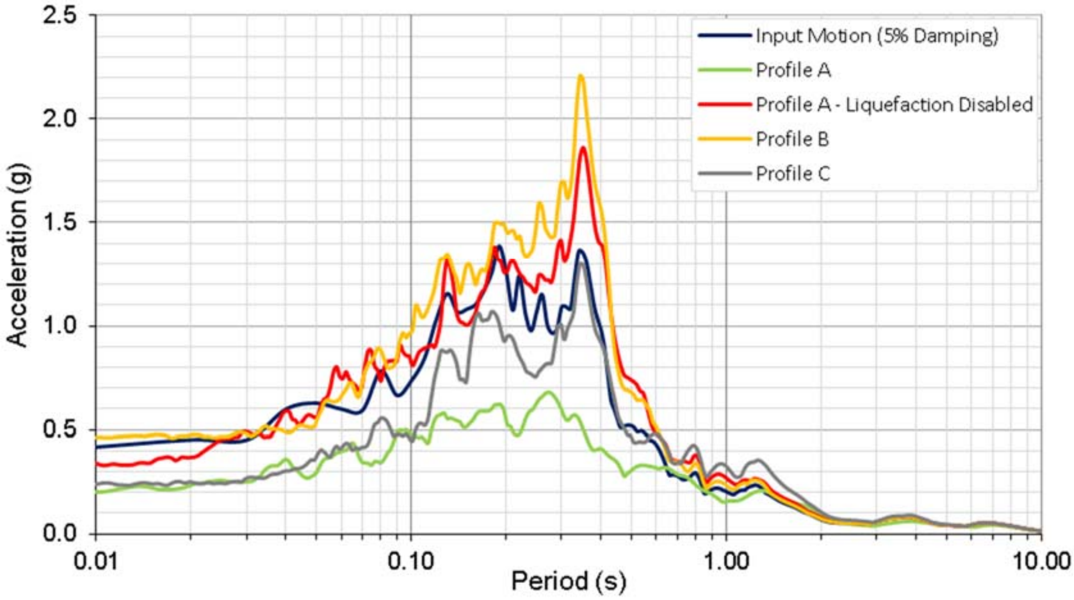

Figure E.3: Düzce records' NS component horizontal acceleration spectra.

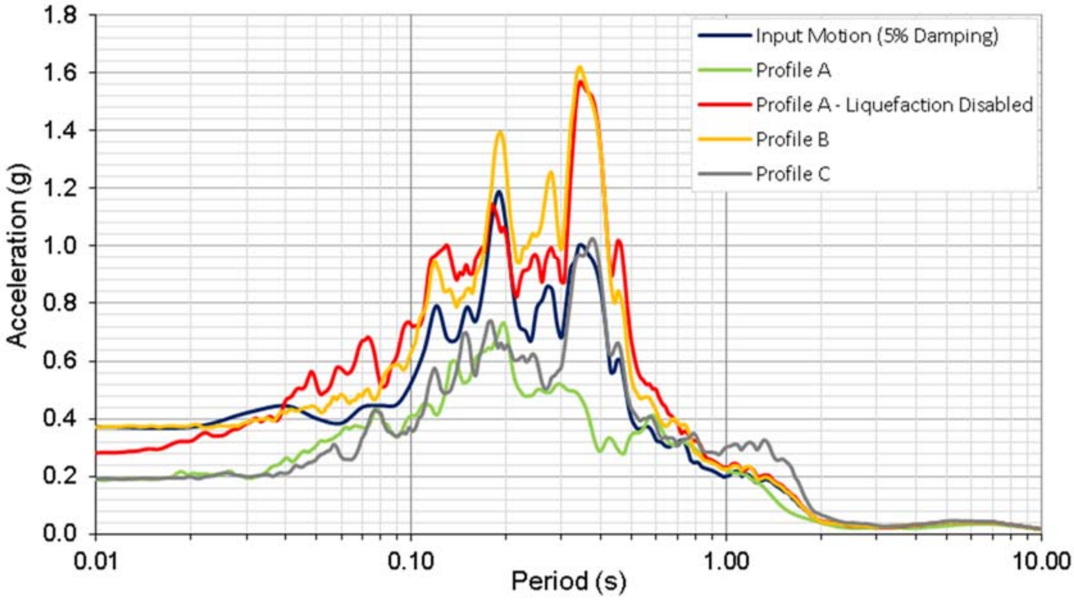

Figure E.4: Düzce records' EW component horizontal acceleration spectra.

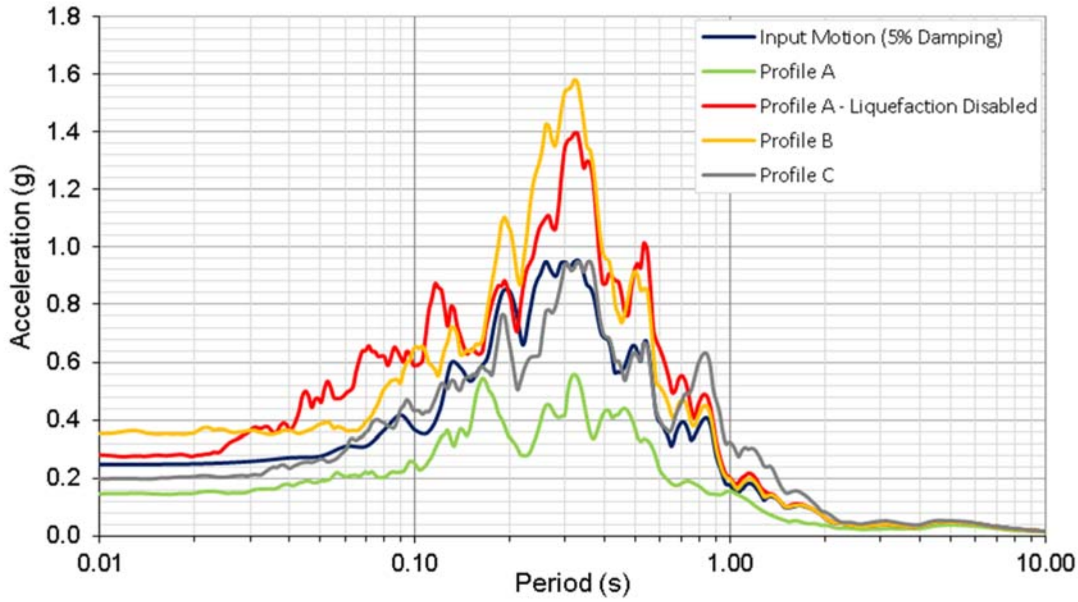

Figure E.5: Landers records' LN component horizontal acceleration spectra.

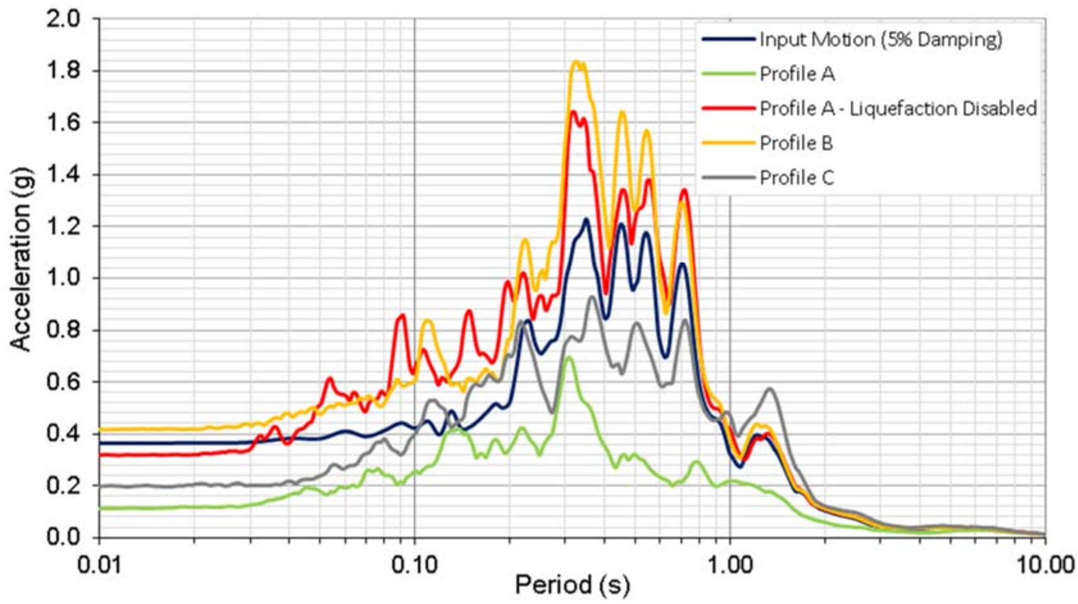

Figure E.6: Landers records' TR component horizontal acceleration spectra.

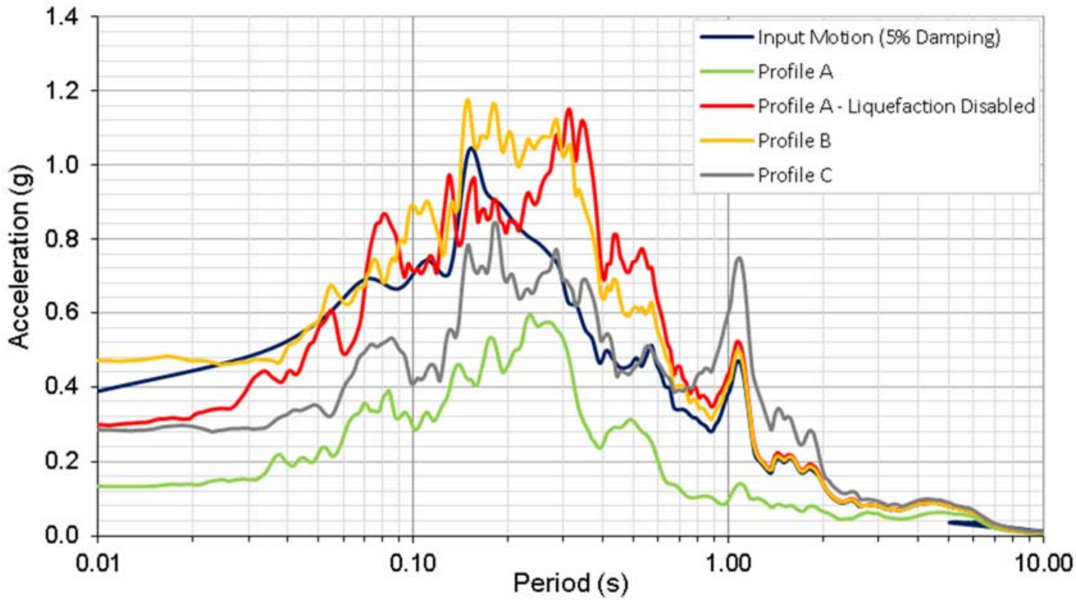

Figure E.7: Darfield records' 17° east component horizontal acceleration response spectra.

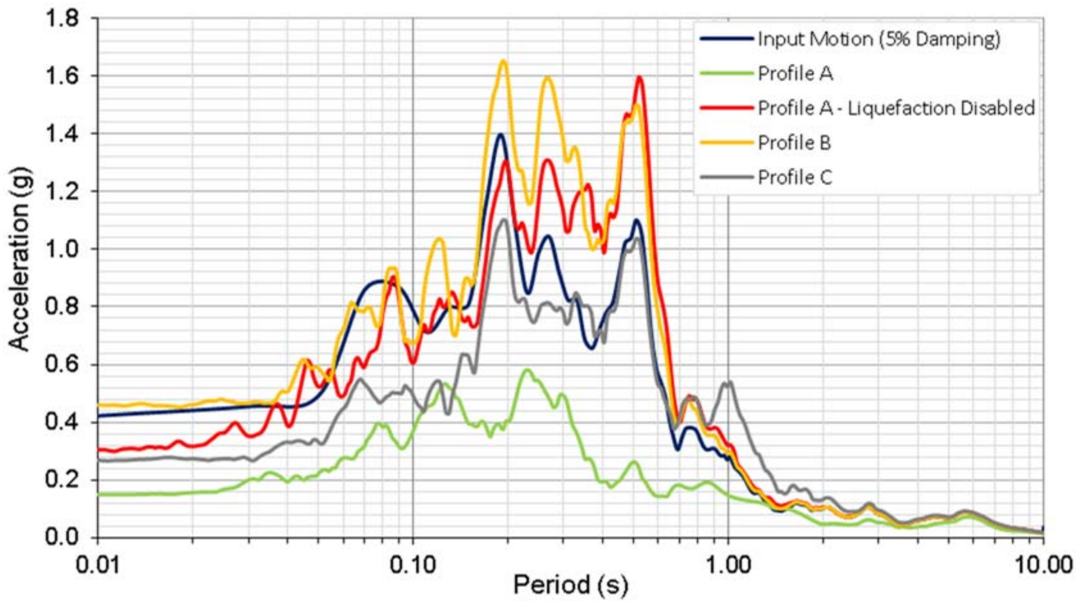

Figure E.8: Darfield records' 73° west component horizontal acceleration response spectra.

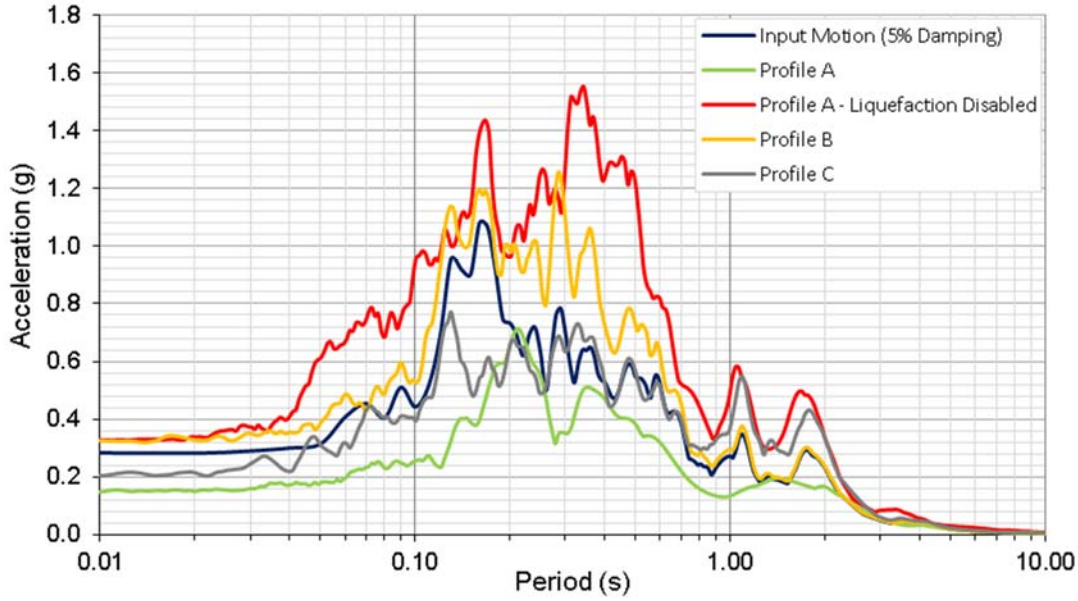

Figure E.9: Kobe records' NS component horizontal acceleration spectra.

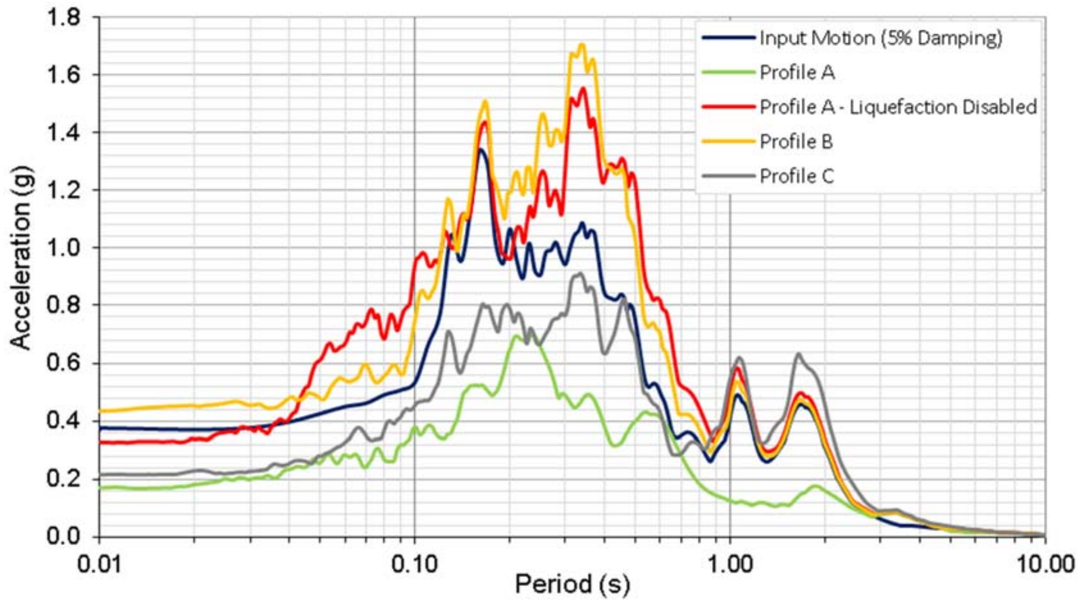

Figure E.10: Kobe records' EW component horizontal acceleration spectra.

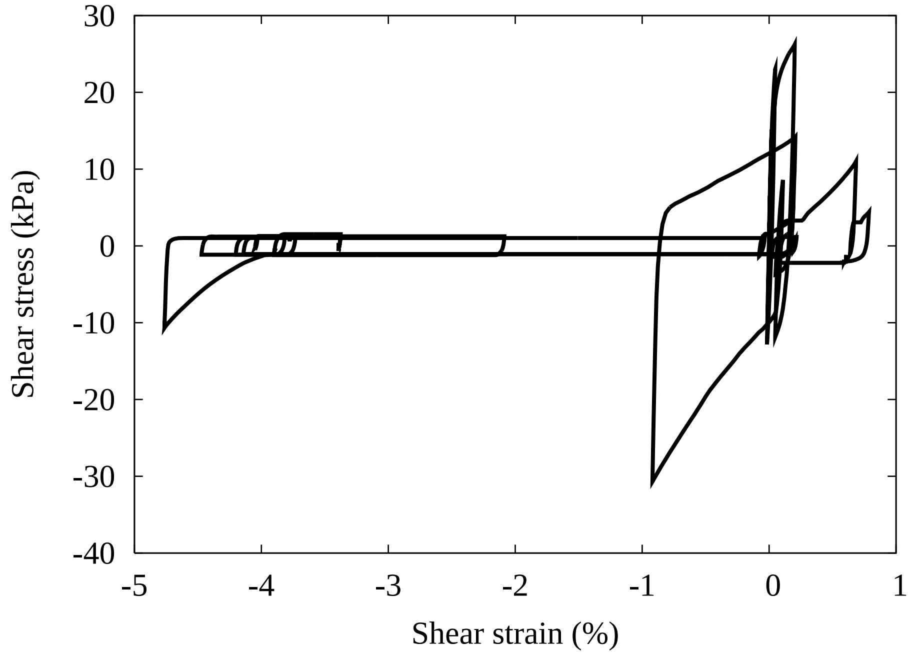

Figure E.11: Shear Stress vs. Shear Strain for Izmit records' NS component (Depth: 9.5 m)

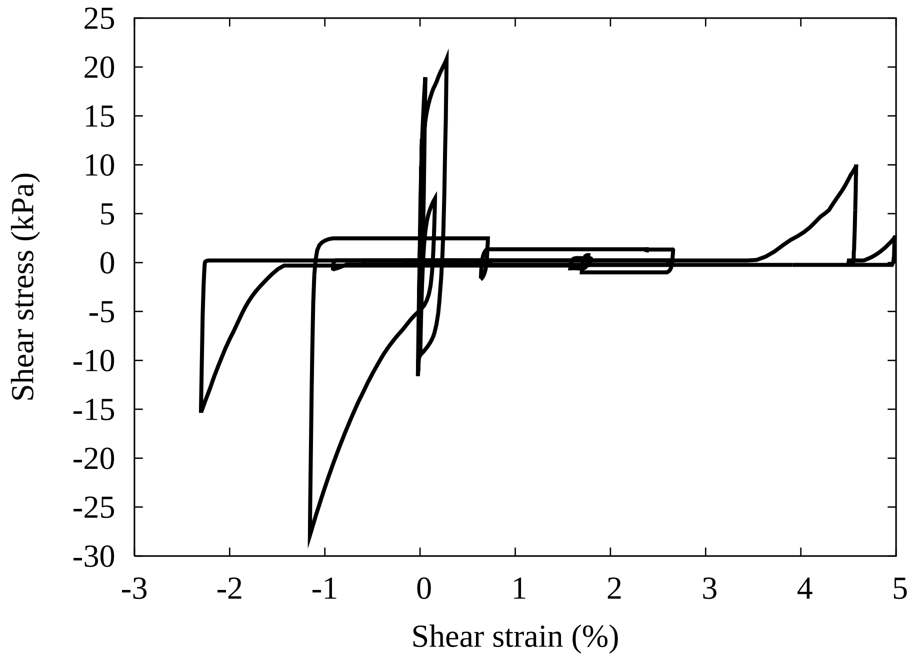

Figure E.12: Shear Stress vs. Shear Strain for Izmit records' NS component (Depth: 7.5 m)

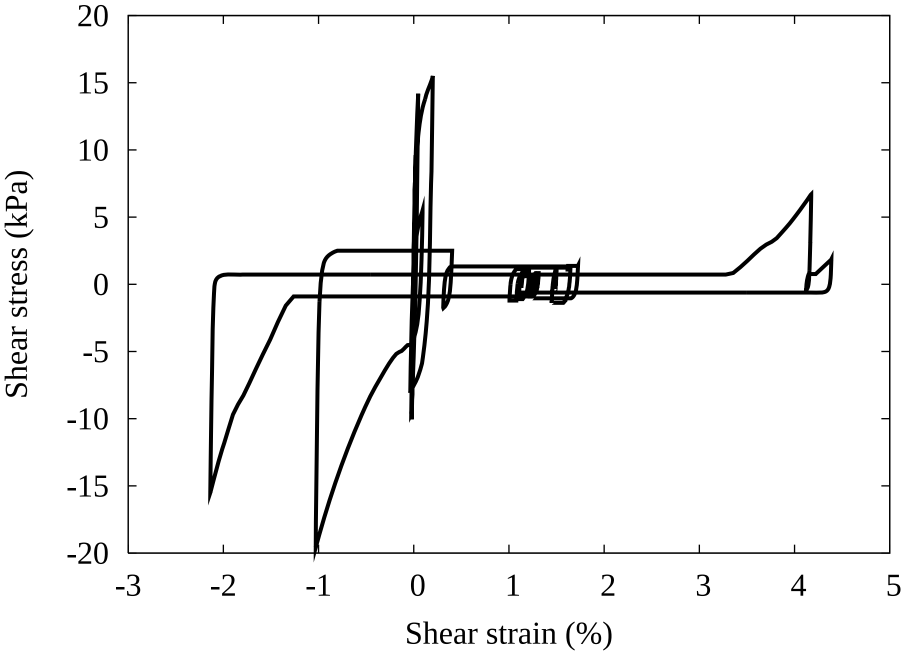

Figure E.13: Shear Stress vs. Shear Strain for Izmit records' NS component (Depth: 5.5 m)

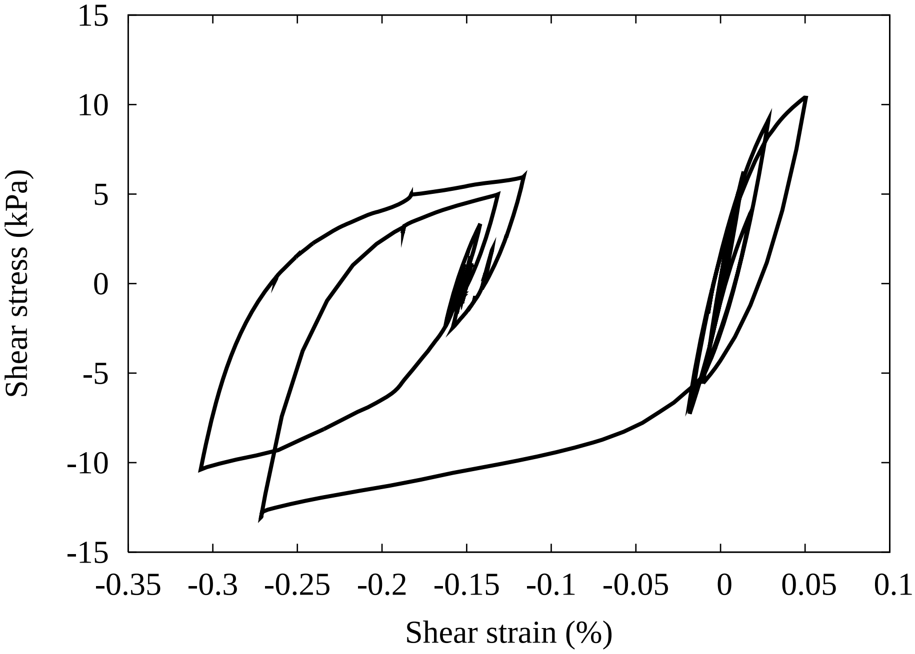

Figure E.14: Shear Stress vs. Shear Strain for Izmit records' NS component (Depth: 3.5 m)

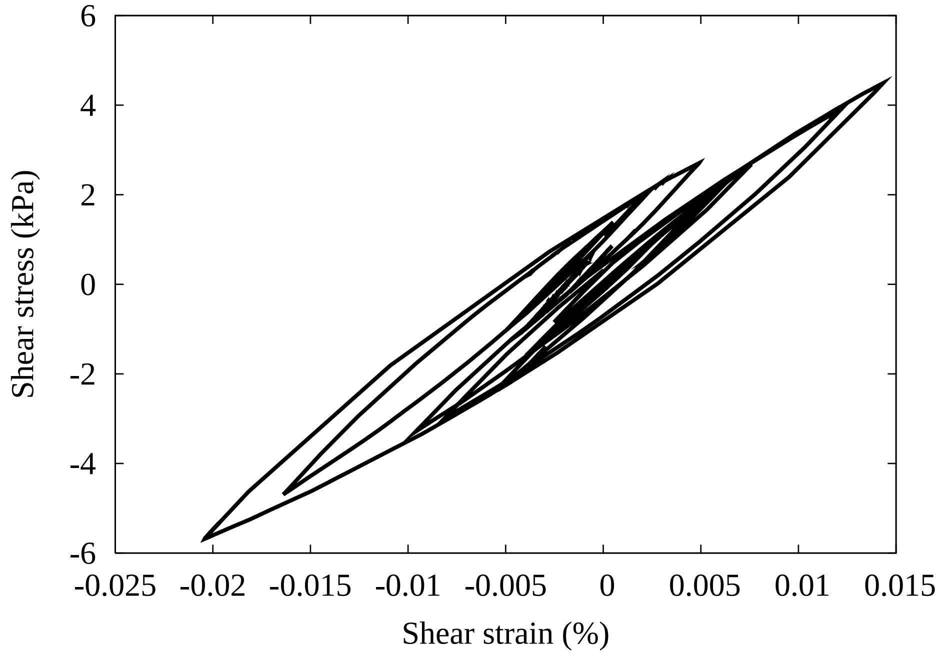

Figure E.15: Shear Stress vs. Shear Strain for Izmit records' NS component (Depth: 1.5 m)

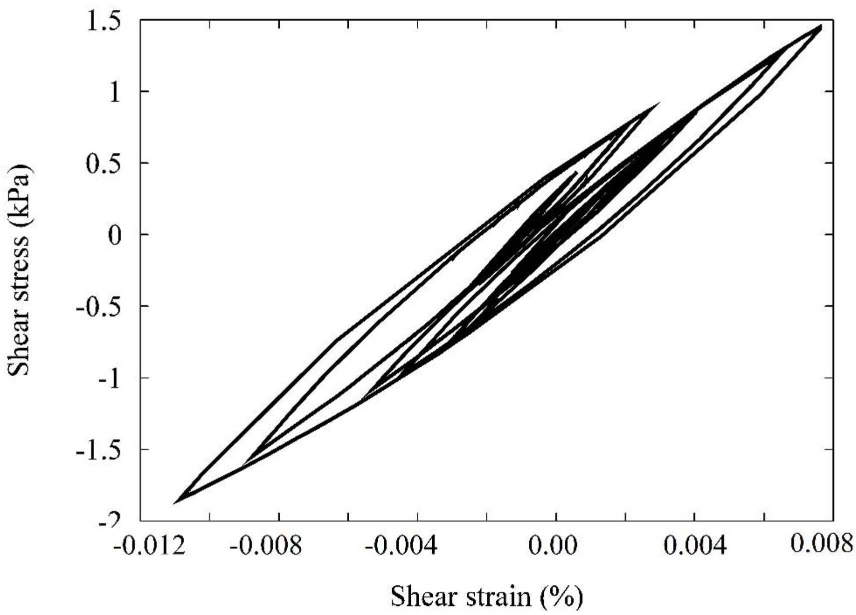

Figure E.16: Shear Stress vs. Shear Strain for Izmit records' NS component (Depth: 0.5 m)