REPUBLIC OF TÜRKİYE
HASAN KALYONCU UNIVERSITY
GRADUATE EDUCATION INSTITUTE
DEPARTMENT OF CIVIL ENGINEERING

EARTHQUAKE RESPONSE ANALYSIS OF ELAZIG-SURSURU USING DEEPSOIL SOFTWARE

Rüveyda EMANET YILMAZ

M.Sc. THESIS

IN

CIVIL ENGINEERING

GAZİANTEP

Earthquake Response Analysis of Elazıg-Sürsürü Using Deepsoil Software

M.Sc. Thesis

İn

Civil Engineering Department

Hasan Kalyoncu University

Supervisor

Assist. Prof. Dr. Nurullah AKBULUT

by

Rüveyda EMANET YILMAZ

November 2023

GRADUATE EDUCATION INSTITUTE
MASTER'S THESIS ACCEPTANCE AND APPROVAL FORM

Civil Engineering Department, student of the Master of Civil Engineering program Rüveyda EMANET YILMAZ prepared and submitted the thesis titled "Earthquake Response Analysis Of Elazig-Sursuru Using Deepsoil Software" and defended successfully at the date of 06/11/2023 and accepted by the jury as a M.Sc. Thesis.

Position	Title, Name and Surname	University	Signature
Supervisor	Assist.Prof. Dr. Nurullah AKBULUT	Hasan Kalyoncu University	
Jury Member	Prof. Dr. Hanifi ÇANAKÇI	Hasan Kalyoncu University	
Jury Member	Assoc. Prof.Dr. M. Eren GÜLŞAN	University of Gaziantep	

This thesis is accepted by the jury members selected by institute management board and approved by institute management board.

Prof. Dr. M. Serhat YENİCE
Director

TEZ BİLDİRİMİ

Bu tezdeki bilgilerin etik davranış ve akademik kurallar çerçevesinde elde edildiğini ve tez yazım kurallarına uygun olarak hazırlanan bu çalışmada bana ait olmayan her türlü ifade ve bilginin eksiksiz atıf yapıldığını bildiririm.

DECLARATION PAGE

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

İmza

Rüveyda EMANET YILMAZ

HASAN KALYONCU UNIVERSITY
GRADUATE EDUCATION INSTITUTE
DEPARTMENT OF CIVIL ENGINEERING

EARTHQUAKE RESPONSE ANALYSIS OF ELAZIG-SURSURU USING DEEPSOIL SOFTWARE

Rüveyda EMANET YILMAZ

MASTER THESIS

Supervisor
Assist. Prof. Dr. Nurullah AKBULUT

ABSTRACT

Earthquakes are a natural occurrence that can have a significant impact on millions of people worldwide each year. Türkiye is situated in one of the most seismically active regions in the world and has experienced numerous destructive earthquakes in recent decades. Elazig, a province in Türkiye, is located in an area prone to high seismic activity. On January 24, 2020, the Elazig-Sivrice district was struck by a powerful earthquake measuring Mw=6.8 at 20:55 local time. Tragically, this event resulted in extensive destruction, including structural damage and loss of life. This study aims to present findings and results regarding the earthquake's seismic impact. The objective is to minimize the impact of future earthquakes and provide recommendations based on seismic parameters. Significant structural damage occurred in the Elazig-Sürsürü neighborhood, primarily composed of young sediments classified as brown gravelly sandy clay, with a groundwater table located below a depth of 15 meters. In order to conduct this study, geotechnical and geophysical data about the Sürsürü district were collected from 72 boreholes to create an idealized soil profile. The investigation was conducted in two stages. Initially, seismic site response analyses were carried out using DEEPSOIL (7.0) software. Subsequently, the collected seismic parameters were used to create seismic site zoning maps using geographic information system (GIS). Additionally, this study aimed to create maps of site dominant vibration period (T_0), shear wave velocity (Vs_{30}), and velocity ratio (Vp/Vs). Finally, a seismic hazard assessment specific to the Elazig-Sürsürü neighborhood was developed as part of the study's conclusions. The results indicated that the groundwater level in the area varies between 3 meters and 16 meters, with some areas having no encountered groundwater. Based on the NEHRP soil classification, the study area is predominantly composed of Class D soils, with occasional areas of Class C soils. The soil types in the Sür sürü neighborhood primarily consist of CL (low plasticity clay), occasionally CH (high plasticity clay), SM (medium plasticity silt), and SM (silty sand). The shear wave velocity ranges from 190 to 365 m/sec, the Vp/Vs ratio from 1.9 to 3.45, and T_0 from 0.47 to 0.66. The highest ground amplification among the 11 earthquakes analyzed was calculated as 4.3 in the Coyote earthquake, while the lowest ground amplification was calculated as 0.71 in the Kobe earthquake. It is important to note that inaccuracies in the geotechnical borehole data used may impact the study's findings, as the collected data were assumed to be valid and representative throughout the analysis.

Keywords: Earthquake, Elazığ, Deepsoil, site effect, spectrum analysis, soil amplification, mapping.

HASAN KALYONCU ÜNİVERSİTESİ
LİSANSÜSTÜ EĞİTİM ENSTİTÜSÜ
İNŞAAT MÜHENDİSLİĞİ BÖLÜMÜ

ELAZIĞ-SÜRSÜRÜ MAHALLESİNİN DEEPSOIL YAZILIMI KULLANILARAK DEPREM TEPKİ ANALİZİ

Rüveyda EMANET YILMAZ

YÜKSEK LİSANS TEZİ

Danışman
Dr. Öğr. Üyesi Nurullah AKBULUT

ÖZET

Depremler, dünya çapında milyonlarca insanı etkileyen doğal olaylardır. Türkiye, son yıllarda bir dizi yıkıcı deprem yaşamış olan dünyanın en aktif deprem bölgelerinden birinde yer almaktadır. Elazığ ili, yüksek deprem riski taşıyan bir bölgede konumlanmaktadır. 24 Ocak 2020'de, yerel saatle 20:55'te, Elazığ-Sivrice ilçesinde Mw=6,8 büyüklüğünde şiddetli bir deprem meydana gelmiştir. Bu olay, önemli yapısal hasarlar ve can kayıplarına neden olmuştur. Bu çalışma, depremin sismik etkileri üzerine elde edilen bulguları sunmayı ve gelecekteki depremlerin etkilerini azaltmaya yönelik sismik parametrelerle ilgili önerilerde bulunmayı amaçlamaktadır. Elazığ-Sürsürü mahallesindeki yapısal hasarlar, genç alüvyon zeminlerin hakim olduğu bir alanda görülmektedir. Bölgedeki zemin özelliklerini anlamak için 72 sondajdan elde edilen geoteknik ve jeofizik veriler, idealize edilmiş bir zemin profili oluşturulmasında kullanılmıştır. Çalışma, DEEPSOIL (7.0) yazılımı ile yapılan sismik site yanıt analizleri ve coğrafi bilgi sistemleri (CBS) kullanılarak elde edilen sismik parametreler ile ilerlemiştir. Sürsürü mahallesinin zemin tipleri, düşük plastisiteli kil (CL), yüksek plastisiteli kil (CH), orta plastisiteli silt (SM) ve killi kum (SM) gibi çeşitli sınıflarda bulunmaktadır. Kesme dalgası hızı, yerel zeminin özelliklerine bağlı olarak değişmekte olup, Vs30 (kesme dalgası hızı) ve Vp/Vs (kesme ve sıkışma dalgası hızı oranı) gibi parametrelerin değerleri incelenmiştir. Sonuçlar, bölgedeki yeraltı su seviyelerinin 3 ila 16 metre arasında değişkenlik gösterdiğini, bazı bölgelerde ise yeraltı suyunun tespit edilemediğini göstermektedir. Elde edilen NEHRP zemin sınıflandırması, D sınıfı zeminlerin yaygın olduğunu, bazı bölgelerde ise C sınıfı zeminlerin bulunduğunu belirtmektedir. Bu çalışma, deprem etkisi altında zeminin davranışını analiz etmeyi ve buna dayalı olarak sismik tehlike değerlendirmesi yapmayı amaçlamaktadır. Kesme dalgası hızı 190 ile 365 m/sn arasında, Vp/Vs oranı 1.9 ile 3.45 arasında ve T_0 değeri 0.47 ile 0.66 arasında değişmektedir. Analiz edilen 11 deprem arasında, en yüksek zemin büyütmesi Coyote depreminde 4.3 olarak hesaplanırken, en düşük zemin büyütmesi Kobe depreminde 0.71 olarak hesaplanmıştır. Çalışma, geoteknik sondaj verilerinin kesinliğindeki belirsizliklerin sonuçları etkileyebileceğini dikkate almalıdır, çünkü bu veriler çalışma boyunca temsilci kabul edilmiştir ancak kesinliği garantilenememektedir.

Anahtar Kelimeler: Deprem, Elazığ, Deepsoil, zemin etkisi, spektrum analizi, zemin büyütmesi, haritalandırma.

ACKNOWLEDGMENT

I would like to thank my valuable thesis advisor Assist. Prof. Dr. Nurullah AKBULUT for his support and contributions at every stage of my thesis. I would like to thank him for all his efforts to be with me in all the negative situations we encountered in this process and not to break my desire to work, and for his guidance to my profession and my master's thesis.

I would like to thank the staff of the Directorate of Reconstruction and Urbanization working within the Elazig Municipality, Elazig Municipality, for enabling us to use the necessary resources to create the database.

I would like to thank Prof. Dr. Alper SEZER, my esteemed teacher from Ege University, for helping me learn the Deepsoil program, which I did not know at all, for his knowledge about earthquakes, and for being with me with all kinds of support, knowledge and experience in various difficulties I encountered with the Deepsoil program during the thesis process,

I would like to thank my dear brother, Geological Engineer Hacı Bayram TAŞKIRAN, who helped us to provide all the necessary protection of the study area and to overcome many difficulties during the data collection process.

I would like to thank my esteemed colleague Olcay POLAT, Civil Engineer (M.Sc.), for correcting my mistakes regarding the problems I consulted him and for patiently responding to me,

I would like to thank Cahit ÖZEN, Geological Engineer (M.Sc.), whom I met during this thesis study, for his help in drawing all the maps used in the results section,

And finally, I would like to thank my dear husband Timuçin YILMAZ for living all the good and difficult moments of my thesis process with me, for always being with me financially and morally, and for supporting me, I express my infinite respect, love and gratitude.

Rüveyda EMANET YILMAZ
Gaziantep – 2023

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS OR SYMBOLS LIST

DD-1 Level of earthquake ground motion with a 2% probability of exceedance in 50 years (recurrence period 2475 years)

DD-2 Level of earthquake ground motion with a 10% probability of exceedance in 50 years (recurrence period 475 years)

DD-3 Level of earthquake ground motion with 50% probability of exceedance in 50 years (recurrence period 72 years)

DD-4 Level of earthquake ground motion with a 68% probability of exceedance in 50 years (recurrence period 43 years)

F_s Coefficient of local soil effect for short period region

F_1 Coefficient of local soil effects for 1.0 second period

g Gravitational acceleration (m/sec^2)

$S_{ae}(T)$ Spectral acceleration of horizontal elastic design (g)

$S_{eaD}(T)$ Spectral acceleration of vertical elastic design (g)

S_{DS} Coefficient of spectral acceleration for short period design (dimensionless)

S_{D1} Coefficient of spectral acceleration for period design S = 1.0 sec (dimensionless)

S_S Coefficient of spectral acceleration for short period map (dimensionless)

S_1 Coefficient of spectral acceleration for 1.0 sec period (dimensionless)

T Natural vibration period (sec)

T_A Spectral acceleration of horizontal elastic design corner period (sec)

T_{AD} Vertical elastic design acceleration spectrum corner period (sec)

T_B Horizontal elastic design acceleration spectrum corner period (sec)

T_{BD} Vertical elastic design acceleration spectrum corner period (sec)

T_L Transition to the constant displacement region in the horizontal elastic design spectrum period (sec)

T_{LD} Transition to the constant displacement region in the vertical elastic design spectrum period (sec)

$(V_S)_{30}$ Average shear wave velocity in the upper 30 meters (m/sec)

V_S Shear wave velocity (m/sec)

V_P Longitudinal wave velocity (m/sec)

T_0 Site dominant vibration period (sec)

A_0 Coefficient of effective ground acceleration

A_{kM} Relative ground magnification factor

λ	Wave length
μ	Bulk Modulus (kg/cm^2 - N/m^2)
ρ	Density (kg/m^3)
E	Young modulus (N/m^2)
σ	Poissons ratio
PGA	Peak ground acceleration (g)
PGV	Peak ground velocity (cm/sec)
PSA	Peak spectral acceleration (g)
α	Impedance ratio
G_{max}	Shear modulus (kg/m^2)
γ_n	Natural (total) unit volume weight (kN/m^3)
H	Thickness of the soil layer over the bedrock
K_0	Coefficient of lateral earth pressure
TBDY	Türkiye Earthquake Regulations for Buildings
NEHRP	National Earthquake Hazards Reduction Program
MASW	Multi-channel Analysis of Surface Wave
MTA	Mineral Research and Exploration
AFAD	Disaster and Emergency Management Presidency

INTRODUCTION

1.1.General

The expansion of cities and the growing population necessitate the identification of new development areas. In both Türkiye and other parts of the world, alluvial soils are favored as suitable locations for urban settlements. This is due to the ease of excavation and filling processes during construction, efficient progress with the initial stages of building construction, and convenient transportation logistics. However, countries like Türkiye, situated on tectonic belts with highly active earthquake zones, have repeatedly experienced the severe impact of earthquakes on these alluvial areas. These sedimentary soils can transform earthquakes, causing numerous fatalities and turning into natural disasters. Therefore, for countries facing significant earthquake risks, it is crucial to find appropriate areas for new construction, address ground issues in buildings renovated during urban transformations, assess local ground properties, and evaluate the effects of ground motions. Cities located in active earthquake zones are obligated to predict structural and spatial damage and implement precautionary measures to mitigate the destructive consequences of earthquakes (Taş, 2003).

Soil investigation studies are an essential part of the pre-construction process. These studies aim to identify crucial parameters such as the condition and depth of underground layers, the type of geological structure, and the foundation soil in both existing and new settlement areas where buildings will be constructed, including urban transformation projects. Geotechnical engineers utilize the data obtained from these studies to assess the behavior of soils under both static and dynamic loads. Particularly important is the understanding of how the ground will respond when subjected to dynamic loads like earthquakes, as this information guides the engineering design process. The primary objective is to comprehend the various variables present in the soil and determine how the building, once constructed, will perform in response to earthquakes (Ekinci, 2011).

Türkiye is located on the boundaries of the Eurasian, Arabian, and African plates, making it an earthquake-prone country. Within these boundaries, active tectonic structures such as the North Anatolian Fault Line and the East Anatolian Fault Line have formed, resulting in 47 earthquakes of 6.5 Mw and above in the past century alone. One such earthquake occurred in Kahramanmaraş province on the Eastern Anatolian

Fault Line, where two quakes measuring 7.6 and 7.7 Mw struck just nine hours apart from each other. This event caused extensive damage. In addition to the Kahramanmaraş earthquake, the Sivrice-Doğanyol earthquake measuring 6.8 Mw that hit Elazığ a few years earlier, on January 24, 2020, severely damaged many buildings, rendering them unusable. Elazığ is located in the Eastern Anatolia Fault Zone, which is an active, strike-slip fault zone running in the NE-SW direction and responsible for the region's seismicity. Geological, geotechnical and geophysical investigations are the first steps taken to evaluate the effects of natural disasters such as earthquakes, which can quickly turn into natural disasters (Çetin and Güneyli, 2001).

The recent earthquakes that occurred along the Eastern Anatolian Fault line have once again highlighted the fact that many settlements are not constructed following building standards and urban planning regulations. This problem is demonstrated by the severe damages incurred, even in buildings constructed after January 2019, when the 2018 Building Earthquake Regulation (TBDY) was published. The magnitude of damages caused by an earthquake depends on factors such as the structural properties of the ground, the degree of stability of structures, and the seismic ground motion risk component. The location of the fault lines in the area also determines the level of damage caused by earthquakes, as a result of its dynamic interaction with the fragility of the social and economic dynamics of the city and the availability of emergency services. It should be noted that the impact of earthquakes is not only limited to the settlements where they occur but also extends to the entire country. Therefore, earthquakes are a complex set of problems that require a multifaceted approach (Taş, 2003). For this reason, it is important to carry out ground surveys as a preliminary study in the construction areas in the cities, to determine the potential behaviour of the ground condition, to find the ground amplification and related parameters, and to make designs based on geotechnical calculations that will ensure that the buildings will receive the least damage during an earthquake, in order to minimise the damage to be experienced after the earthquake.

Following the Elazığ earthquake, a comprehensive assessment was carried out on 86,595 buildings (consisting of 281,077 independent sections) in the province. The evaluation indicated that a total of 16,606 buildings either collapsed, required immediate demolition, or suffered extensive damage as a result of the earthquake. These numbers are significant, revealing the severity of the damages and highlighting the impact of local soil characteristics, particularly in areas previously used for agriculture.

In 2014, a doctoral thesis by Mahmut Palutoğlu titled "Tectonics, Seismicity, and Microzonation of Elazığ City Centre" emphasized the need for soil improvement before construction in the Sürsürü, Mustafa Paşa, and Kültür districts. Interestingly, these districts were among the most affected areas during the 2020 Elazığ earthquake. Sürsürü, located in the Central District of Elazığ Province, was selected as the study subject of thesis due to its alluvial soil composition, the presence of various construction projects, and the importance of conducting ground investigations for building design in the neighborhood considering these factors.

The study area selected for this research is Sürsürü neighborhood, situated within Elazığ Central district. This region is characterized by the highest thickness of basin fill, ranging from 500-550 meters, and has a groundwater level that can reach up to 3 meters. The soil density, stiffness, and bearing capacity in this area are relatively low. Sürsürü neighborhood has gradually become a settlement area since the 1950s. According to the Turkish Building Earthquake Regulation (TBDY), it is classified as ZD class, indicating medium dense sand gravel or very stiff clay. Additionally, according to the National Earthquake Hazards Reduction Program (NEHRP), the area falls under the "D, Hard / Stiff Soil" type.

1.2. Objective of the Study

The objective of the thesis is to analyze the soil amplification and earthquake characteristics in the Sürsürü District, as well as to generate ground maps by plotting various parameters such as Shear wave velocity (Vs1), seismic velocity ratio (Vp1/Vs1), shear wave velocity at a depth of 30 meters (Vs30), site dominant vibration period (To), and amplification (Ao). These maps will be created using the borehole drilling data obtained from AFAD, in conjunction with the Deepsoil (7.0) displacement results. By utilizing the field and laboratory findings from previous studies on the alluvial soil of Elazığ's Sürsürü District, a comprehensive assessment of the ground conditions will be conducted.

The main objective of this study is to present findings and results related to the seismic impact of earthquakes. The aim is to minimize the effects of future earthquakes and provide recommendations based on seismic parameters. Extensive structural damage was observed in the Elazig-Sürsürü neighborhood, which mainly consists of young sediments categorized as brown gravelly sandy clay. The groundwater table in this area is situated below a depth of 15 meters. To conduct this study, geotechnical and geophysical data will be gathered from the Municipality. The investigation will be carried out in two phases. Firstly, seismic site response analyses will be performed utilizing the DEEPSOIL (7.0) software. Following that, the collected seismic parameters will be utilized to develop seismic site zoning maps using geographic information system (GIS).

1.3.Outline of the Thesis

The Master's Thesis consists of 5 chapters.

Chapter 1 Introduction: In the first chapter, Sürsürü neighbourhood, which is our study area, and why this neighbourhood was chosen as the subject of the study are explained.

Chapter 2 Literature review: In this chapter, a literature review on the Deepsoil software and site response analysis is presented. Also informations on previous studies conducted in this area of research is provided.

Chapter 3 Material and Methods: In this chapter, details about the geographical location, geological characteristics, and seismic activity of Elazığ province are provided. A comprehensive explanation of the SPT, pressuremeter, and MASW field tests, evaluating the boundary parameters and outcomes are given. Furthermore, information about the Deepsoil software and its data entry process is explained.

Chapter 4 Results and Discussion: In this chapter, the maps and graphs created with the results obtained are evaluated and discussed.

Chapter 5 Conclusions: This chapter presents the conclusions of the thesis.

2. LITERATURE REVIEW

2.1. General

Earthquake is the event in which the energy that suddenly emerges in the fractures in the earth's crust spreads in the form of seismic waves and these waves shake the earth. (URL1). The Earth's crust consists of 7 large plates and many smaller plates. Most of the earthquakes occur on narrow belts at the plate boundaries where these plates force each other. (URL1).

There are generally three types of earthquakes. "Tectonic earthquakes" that occur as a result of the tectonic movement of the plates. 90% of earthquakes are tectonic earthquakes. "Volcanic earthquakes" caused by the eruption of volcanoes. "Subsidence earthquakes" caused by all kinds of underground cavities (such as caves, coal mines, gypsum and salt deposits). Volcanic and subsidence earthquakes are localized earthquakes. Some of the earthquakes in Japan and Italy are volcanic earthquakes. Since there are no active volcanoes in Türkiye, there are no volcanic earthquakes (URL1).

The earth's crust moves through earthquakes and thus the world maintains its vitality. Throughout history, many civilizations have collapsed after earthquakes and many new civilizations have been established. The first known earthquake in written history was recorded in China in 780 BC. In addition, the first seismograph was invented in China by the Chinese astronomer and mathematician Chang Heng in 132 A.D. This instrument was named "Earthquake-Air-Horn". Information about this device, which was established in the capital Sian and used for a long-term period, can be found in the "Story of the Later Dynasties". According to the story, this device was a bronze cube with a diameter of 1.80 meters, containing a heavy pendulum and links placed in eight different directions perpendicular to this pendulum. Outside the cube, at the points where the links are, there are eight dragon heads, each with a bronze ball in its mouth. A frog is placed under each dragon head. In the event of an earthquake, since the pendulum will move in the direction of the earthquake, the links will move depending on the pendulum, causing the monster in that direction to open its mouth, and thus the free bronze ball will fall into the mouth of the frog waiting with its mouth open below (Pajak, 2005).

On November 1, 1755, on All Saints' Day, the Lisbon earthquake was the birth of seismology. Seismology means "the science of earthquakes". It is a combination of the Latin words "seismos=earthquake," and "logos=science." Kant, Voltaire and Rousseau initiated philosophical inquiries about earthquakes for the first time and opened the doors of the world of thought to the subject of earthquakes, while Kant published 3 articles, especially "On the causes of earthquakes" (Kramer, 1996; Yılmaz, 2020).

With the 1783 Italian earthquake, an earthquake research commission was established for the first time in history, and the 1819 Cutch earthquake in India is important in terms of being the first well-compiled study on faulting (Kramer, 1996).

1923 Kanto earthquake in Japan. Significant damage in the Tokyo-Yokohama area. Most of the damage was caused by fires in Tokyo and tsunami impact in coastal areas. Significantly influenced the development of design processes in Japan (Kramer, 1996).

1925, 1933, 1940 California earthquakes, the first significant acceleration records for engineering purposes in the USA were compiled by these earthquakes, leading to important seismic design sanctions, and the first significant sanctions on earthquake resistant structures in building codes came into force after these earthquakes (Kramer, 1996).

1960 Chile earthquake, probably the largest earthquake recorded in the last century (Kramer, 1996).

1964 Alaska Good Friday earthquake caused significant damage due to liquefaction and landslides triggered by the earthquake. (Kramer, 1996)

1964 Japan Large areas of liquefaction caused significant damage to structures. Together with the Good Friday earthquake in Alaska, it led to an intense interest in liquefaction (Kramer,1996).

The 1985 earthquake, known as the Mexico City earthquake, had its epicentre in the Pacific Ocean but caused damage in Mexico City, 360 km away. The effects of site ground conditions on ground motion, ground amplification and damage were observed. The earthquake contributed significantly to the understanding of the dynamic properties of fine-grained soils (Kramer, 1996).

In addition to these important earthquakes, of course, there have been many more destructive and large earthquakes in the world. After these earthquakes, great progress was made in seismology step by step with the help of developing technology.

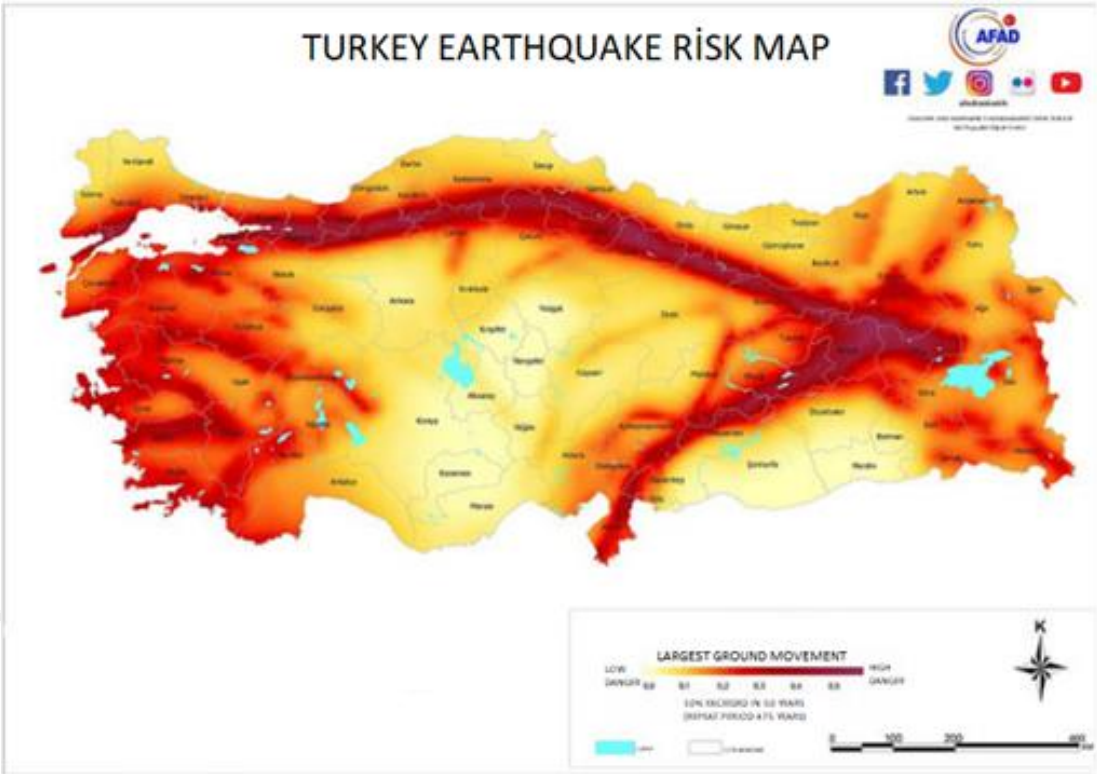


Figure 2.1. Fault map of Türkiye (URL2)

Türkiye has a young, high altitude terrain formed in the 3rd and 4th centuries. The elevation increases from west to east. The average elevation is 1141 m above sea level. Located in the Alpine orogenic mountain belt, Türkiye is active tectonics and is a country with high earthquake frequency and damage risk. There are two main fault zones, particularly the East Anatolian and North Anatolian faults, and many local faults in Türkiye, which periodically produce large earthquakes. Türkiye is an earthquake country with active fault lines within its borders and is one of the important earthquake zones of Europe. For this reason, earthquake structure design is important. (Elibüyük and Yılmaz, 2010)

The first recorded earthquake in the history of Türkiye was the Lydian earthquake in 17 AD, known as the Asia Minor earthquake. This earthquake destroyed at least twelve cities in the Lydian region of the Roman province of Asia in Anatolia. Recorded by Roman historians Tacitus and Pliny the Elder, and Greek historians Strabo and Eusebius, it was described by Pliny the Elder as "the greatest earthquake in human memory". The city of Sardis, the former capital of the Lydian Empire, was hit hardest by this earthquake and was never fully recovered from its destruction in later times. Although BC earthquake records such as Lysimakheia Earthquake (287 BC), Ophryneion Earthquake (360 BC), Perinthos Earthquake (399-395 BC), Aigaios Pontos Earthquake (426 BC), Poteidaia Earthquake (479 BC) are available, sources before the 8th century BC are insufficient or unreliable. Again, it is possible to find traces of volcanic eruptions and earthquakes even in some wall paintings drawn in Çatalhöyük Neolithic Age settlement in 6200 BC. (Karagöz, 2005; Yıldırım and Nişancı, 2023; Doğancı, 2019) As it is understood from this, Anatolia has been an earthquake zone throughout history. The map below shows the major earthquakes in Anatolia in the last 500 years before the establishment of the Republic of Türkiye.

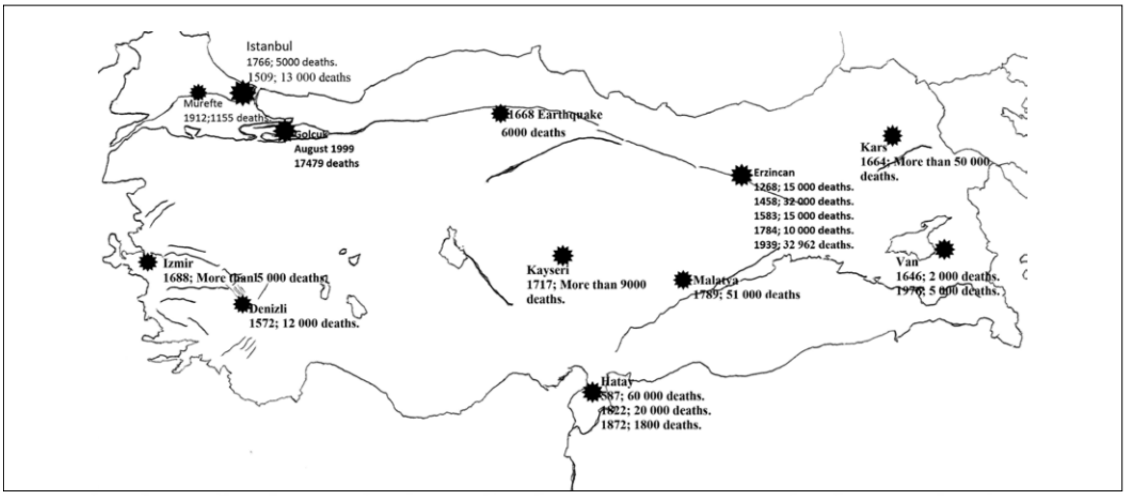


Figure 2.2. Some of devastating and deadly earthquakes in major cities in Türkiye in the past (Gündüz et al., 2012)

Table 2.1. Table of earthquakes of 6.5 Mw and above in the last 50 years in Türkiye (URL3)

Date	Origin Time	Latitude	Longitude	Depth(km)	xM	Location
2023.02.06	10:24:47.88	38.0818	37.1773	005.0	7.6	Ekınozu (Kahramanmaras) [North West 2.7 Km]
2023.02.06	01:28:16.94	37.2337	36.7805	005.0	6.6	Belpınar-Nurdagı (Gazıantep) [North East 2.0 Km]
2023.02.06	01:17:32.67	37.1757	37.0850	005.5	7.7	Yamacoba-Sehıtkamıl (Gazıantep) [North West 0.4 Km]
2020.10.30	11:51:24.37	37.8877	26.7057	011.2	6.9	Ege Denızı
2020.01.24	17:55:10.61	38.3922	39.0847	005.0	6.7	Kalaba-Sıvrıce (Elazıg) [North West 2.5 Km]
2017.07.20	22:31:09.66	36.9693	27.4057	007.1	6.6	Gokova Korfezı (Akdenız)
2011.10.23	10:41:21.01	38.7212	43.4110	005.0	7.2	Yemlıce- (Van) [North West 1.5 Km]
1999.11.12	16:57:20.80	40.7400	31.2100	0025	7.2	Ugur- (Duzce) [North East 0.3 Km]
1999.08.17	00:01:37.60	40.7600	29.9700	0018	7.4	Basıskele (Kocaelı) [North East 2.0 Km]
1992.03.13	17:18:39.40	39.7200	39.6300	0023	6.8	Gunebakan- (Erzıncan) [South West 1.7 Km]
1988.12.07	07:41:24.30	40.9600	44.1600	0005	6.7	Azerbaycan
1983.10.30	04:12:28.10	40.3500	42.1800	0016	6.8	Parmakdere-Sarıkamıs (Kars) [North West 4.2 Km]
1976.11.24	12:22:16.00	39.0500	44.0400	0010	7.5	Yenıyaka-Caldıran (Van) [South East 1.9 Km]
1975.09.06	09:20:12.00	38.5100	40.7700	0032	6.6	Ucdamlar-Lıce (Dıyarbakır) [West 1.6 Km]
1975.03.27	05:15:07.90	40.4500	26.1200	0015	6.7	Saros Körfezı (Ege Denızı)
1971.05.22	16:43:59.30	38.8500	40.5200	003.0	6.8	Guveclı- (Bıngol) [North West 0.7 Km]
1970.03.28	21:02:23.50	39.2100	29.5100	018.0	7.0	Kızık-Cavdarhısar (Kütahya) [North 0.8 Km]

As can be seen, earthquakes of 6.9 Mw and above on the 2 main fault lines in Anatolia are considerable. If we consider the information and data of the earthquake with a magnitude of 6.8 Mw that occurred in Elazığ on 24.01.2020 and two earthquakes with a magnitude of 7.8 Mw and 7.5 Mw, which occurred nine hours apart on 06.02.2023 in Pazarcık and Ekinözü districts of Kahramanmaraş, the seriousness of the situation becomes clear. Considering that 42% of Türkiye is located in first-degree, 24% in second-degree and 18% in third-degree earthquake zones (Sönmez, 2011) and 71% of our population lives in first and second degree earthquake zones (Sönmez, 2011; Türkoğlu, 2001), it becomes clear that earthquake in Türkiye is not only a natural disaster causing loss of life and property, but also a national security problem.

In our country, where earthquakes occur continuously, various studies have been carried out depending on the damages that occur especially after major earthquakes, and in the light of these studies, regulations have been prepared to define how manufacturing and design should be in the design of structures related to earthquakes. These regulations are listed chronologically below.

- Italian Building Instructions for Construction in Zelzele Areas (1940)

- Zelzele Zones Temporary Construction Regulations (1944)
- Türkiye Earthquake Zones Building Regulations (1949)
- Regulation on Structures to be Built in Earthquake Zones (1953)
- Regulation on Structures to be Built in Disaster Areas (ABYYHY-1962)
- Regulation on Structures to be Built in Disaster Areas (ABYYHY-1968)
- Regulation on Structures to be Built in Disaster Areas (ABYYHY-1975)
- Regulation on Structures to be Built in Disaster Areas (ABYYHY-1998)
- Regulation on Buildings to be Built in Earthquake Zones (DBYBHY-2007)
- Türkiye Building Earthquake Regulations (TBDY-2018)

(Adar et al., 2021)

Table 2.2. In the table of the 2019 regulation, four different levels of earthquake ground motion are defined within the scope of the regulation. (TBDY, 2018)

Earthquake Ground Motion Level-1 (DD-1)	Earthquake Ground Motion characterises very infrequent earthquake ground motion where the probability of exceeding the spectral magnitudes in 50 years is 2% and the corresponding recurrence period is 2475 years. This earthquake ground motion is also referred to as the largest earthquake ground motion considered.
Earthquake Ground Motion Level-2 (DD-2)	Earthquake ground motion is characterised by infrequent earthquake ground motion with a 10% probability of exceeding the spectral magnitudes in 50 years and a corresponding recurrence period of 475 years. This earthquake ground motion is also called standard design earthquake ground motion.
Earthquake Ground Motion Level-3 (DD-3)	Earthquake Ground Motion characterises frequent earthquake ground motion where the probability of exceeding the spectral magnitudes in 50 years is 50% and the corresponding recurrence period is 72 years.
Earthquake Ground Motion Level-4 (DD-4)	Earthquake Ground Motion characterises very frequent earthquake ground motion with a 68% probability of exceeding the spectral magnitudes in 50 years (50% probability of exceeding in 30 years) and a corresponding recurrence period of 43 years. This earthquake ground motion is also called service earthquake ground motion.

Table 2.3. Earthquake ground motion levels (TBDY, 2018)

Earthquake Surface	Repetition Period	Probability of Exceeding (in 50 years)	Description.
DD-1	2475	0.02	Largest earthquake ground motion
DD-2	475	0.1	Largest earthquake ground motion
DD-3	72	0.5	Frequent earthquake ground motion
DD-4	43	0.68	Service earthquake ground motion

While building codes are updated at more frequent intervals in developed countries, unfortunately, in the 100-year history of Türkiye, updates have been made either due to bitter experiences or inadequacy. This inadequacy has returned to us as heavy material and moral losses in major earthquake disasters.

It is known that earthquake waves increase significantly when passing through soft soils compared to hard soils and this increase has a great share in the damage caused by the earthquake. For this reason, in geotechnical engineering, when designing a structure anywhere, it is necessary to know all local soil properties and seismic loads of that soil in order to design earthquake resistant structures. It is essential to know the properties of the soil and its dynamic behaviour in order to understand the behaviour of structures under dynamic loads such as earthquakes. The characteristics of earthquake activity that may occur in a place are related to many factors such as tectonic structure, rupture mechanism, distance from the earthquake source, the effect of geological structure on the propagation path of the earthquake wave in the earth layers, the effect of local topography and soil conditions. While the analysis of the source mechanism and the effect of geological formation on the propagation path of the earthquake wave are within the scope of seismology, the investigation of the effect of local ground properties on strong ground motion is one of the interests of geotechnical engineering. The aim of these studies is to determine the characteristics such as amplitude, frequency content and duration of the spectral acceleration and design earthquake motion that may affect engineering structures during their lifetime. In order to determine the effects of the design earthquake on the surface, all local effects including topographic features and lateral geological irregularities as well as geotechnical properties should be taken into account in the dynamic analysis of soil layers (Iyisan and Haşal, 2006; 2007).

Seismic waves travel through the bedrock towards the surface and pass through different ground layers along the way. Along this path, the differences between the layers make a significant difference in the wave frequency and amplitude felt. Soil layers minimise and dampen some waves and amplify others. This increase in the amplitude of earthquake waves travelling through soil layers is defined as ground amplification in the literature. The amplified motion transmitted to the foundation of the structure increases the deformation levels on the structural elements and results in possible local collapse or structural collapse. Very small values of bedrock accelerations can be amplified several times in some regions with the effect of local conditions and can cause very severe damage (Kramer, 1996). Another reason for soil amplification is that the soil layers on the bedrock have different values of resistivity (impedance). This value, which can be determined from the density of the medium and the shear wave velocity, provides a theoretical basis for showing the effect of local ground conditions on the motion at the surface. In general, the unit volume weights and shear wave velocities, i.e. the specific resistances of the layers in the soil section increase with depth.(Uyanık, 2015)

The largest definite value calculated in terms of acceleration in the time-dependent change of the response of a unit-degree-of-freedom system with a given damping ratio, stiffness and mass under the effect of strong surface motion is called spectral acceleration. The change of spectral accelerations depending on the periods of the system is called acceleration spectrum. (Iyisan and Haşal, 2011)

We learn from the studies that earthquake risk existed in the past, exists today and will exist tomorrow. From a risk control perspective, we will either eliminate the risk or change our settlement area. We can neither eliminate the earthquake nor move the cities with today's conditions. Then there is only one step left; we will apply the right engineering methods and we will start from the ground. Those who manage the cities have to make the right zoning plan and city plans. Only the earthquakes we have experienced in the last 50 years and the subsequent losses show us how serious the job is. Before the ground survey, local governments in each city should be able to conduct microzoning studies on the basis of province, district and even neighborhood and preliminary information about the ground in the region should be obtained.

2.2. Studies Related to Site Response

Geotechnical engineering, geological and geophysical value results are used while working on the ground. The evaluation of the results of both site tests and laboratory tests allows us to identify the characteristic structure of the soil and, accordingly, how the engineering design will be. Many programmes help us in this process. For example, we can calculate ground response analyses in the area under the influence of earthquake records such as Deepsoil 7. In residential areas with high earthquake risk, ground models can be created with DEEPSOIL 7 programme and ground amplification changes can be examined on certain lines. Ground amplification is defined as the increment in the amplitude of earthquake waves as they move through the ground stratum close to the surface. It is hoped that the determination of ground amplification will contribute to the safer construction of manufactured structures. In addition, the results of field and laboratory experiments and maps give us an idea about the ground.

The microzonation study made with the measurement results of these maps in grid form could not be performed due to the insufficiency of the data we have, but this mapping method has guided us. In this study, microzonation could not be carried out because of the lack of boreholes suitable fort he required grid. Instead, maps suitable for geotechnical purposes were prepared for Sürsürü District by making use of field and laboratory results and these mapsnwere evaluated with deepsoil results. Knowing the behaviour of soils due to earthquake movement by using geological, geotechnical and geophysical researches in the study area during the preparation of maps and the data used depending on the results of these researches are of great importance in determining, controlling and/or preventing natural disasters.

During an earthquake, seismic waves travel far away from the earthquake origin and rapidly reach the Earth's surface. After the earthquake waves leave the bedrock, some of them are slaughtered in the rock until they reach the earth's surface, but a significant portion is also slaughtered in the ground. Ground conditions significantly affect the nature of the shaking that occurs at the earth's surface. One of the most important issues in geotechnical earthquake engineering is the effect of local soil conditions on strong ground motion.

As a result of the large and destructive earthquakes experienced in the past, lessons have been learnt to prevent similar situations in the future, to mitigate the effects of earthquakes, and to make the infrastructure more planned has also been a separate subject of study. Seismic hazard is a dangerous situation caused by earthquake. Earthquake Engineering applications determine the identification and mitigation of these seismic hazards as the main objective. Microzonation is a method for pre-earthquake seismic hazard assessment and risk assessment and is defined as zoning according to ground motion characteristics by considering source and site conditions (TC4-ISSMGE, 1999). Microzonation is the most accepted method in its field of study today. Unlike traditional macrozonation maps, by developing regional hazard maps, microzonation of a region produces elaborate maps that estimate hazard at much smaller areas and scales. Seismic microzonation is the general description of breaking down into smaller areas the various hazardous earthquake effects that a region has, with a high probability of occurrence, and defines its specific seismic behaviour for engineering design and land use planning (Sitharam and Anbazhagan, 2008). Although this thesis is not microzonation, its principles have been utilised in the process.

When an earthquake occurs, the waves propagating from the bedrock are impacted by the mechanical features of the ground stratum through which they pass and can be felt more strongly when they reach the earth's surface. Different soil layers change the displacement amplitudes in horizontal and vertical directions while transferring the earthquake waves to the next layer. Bedrock accelerations, which have very small values, can grow several times in some regions with the effect of local conditions and cause very severe damage (Kramer, 1996), this phenomenon is called “ground amplification”.

Seismic motions are generated for different reasons and change in their movement from the bedrock to the surface by being affected by local soil conditions, and depending on the soil type and dynamic properties, they are damped or amplified and transmitted to the surface. This increase in the amplitude of earthquake waves passing through soil layers is defined as ground amplification in the literature. The amplified motion transmitted to the foundation of the structure increases the deformation levels on the structural elements and results in possible local collapse or structural collapse. Very small values of bedrock accelerations can be amplified several times in some regions by the effect of local conditions and can cause very severe damage (Kramer, 1996). For this reason, the dynamic behavior of soils has a great influence on the transmitted motion. The fact that the accelerations recorded from the same earthquake in different locations in close proximity to each other are very different from each other is due to the different ground conditions in the recorded locations. While special soil conditions are required for problems such as liquefaction, settlement and slope stability to occur as a result of the changes caused by earthquake waves in soil layers, ground amplification can occur in almost any soil (İyisan and Haşal, 2011).

As an important factor, soil amplification should be calculated and taken into account before the design process of the work. The emergence of different geotechnical problems due to the fact that earthquakes are affected by local soil conditions has attracted the attention of researchers and different studies have been carried out. As a result of these studies, different soil improvement methods have been tried in order not to be affected by the soil amplification analysis, especially in public buildings and their effect on the soil amplification analysis has been investigated and reductions of up to 50% have been observed (Güllü, 2001; Korkmaz, 2012).

2.3. Studies Related to DEEPSOIL

A study discussing the importance of site-specific dynamic soil properties on the application of SSRA was conducted by Civelekler et al. (2022). Researchers state that there are various analytical models in the literature to predict shear modulus and damping ratio curves based on soil properties (Darendeli, 2001; Menq, 2003).

In the study, the results of the equivalent linear analyses performed on the boreholes whose data were previously used by the researchers were compared with the results of the calculated one-dimensional (1-D) nonlinear analyses (SSRA) for the same boreholes. In addition, the spectrum behaviour based on nonlinear site response analysis for the boreholes was evaluated and the specific site response spectra obtained from the equivalent linear analyses were compared.

It was stated by the researchers in the study that soil behaviour is nonlinear under repetitive loads caused by seismic motion. Due to this problem, it is stated that they consider the hysterical stress-strain relationship of the soil in order to find more accurate results than the equivalent linear approach. It is also stated that the nonlinear soil behaviour analyses are time domain analyses and they reveal nonlinear soil behaviour by using stress-strain properties.

Within the scope of nonlinear analyses, 42 vertical strings were stimulated by 11 real-scale earthquake records grouped in 4 areas representing the region and Civelekler and Afacan performed a total of 462 nonlinear site response analyses and evaluated the spectral acceleration and amplitude behaviour for each borehole as a result of the analyses. According to the study, they found that the highest spectral accelerations and the highest amplitudes using the equivalent linear approach resulted at low and medium periods, but at higher periods the predictions were like for both the equivalent linear and non-linear approaches.

In the study, Civelek et al. (2022), who revealed various predictions in the comparisons between equivalent linear and nonlinear analyses, stated that the parameters aquired from the results of the equivalent analysis are closer than the nonlinear analysis when compared with the design parameters, and made predictions with the two methods by considering the earthquake characteristics in addition to the ground design. They stated that the literature promote the opinion of that there is a propensity for the equivalent linear approach to predict higher acceleration and shear stress under large amplitude motions, however, the correlation between equivalent and nonlinear behaviour is not completely closed.

The researchers stated that the phases of a region response analysis are territorial distress, site characterisation, choice of input ground motion and 1-D site response analysis, and that site characterisation, characteristics and depth of soil layers, dynamic shear modulus, reduction of dynamic shear modulus, depth of engineering bedrock and shear wave velocity should be determined in the content of the site response analysis. The researchers emphasised that equivalent and nonlinear approaches are preferable in both practice and literature, but the results may vary depending on the site characteristics.

On 30 October 2020, during the Aegean Sea earthquake with a magnitude of Mw=6.9, Bayraklı district of Izmir province, 70 km away from the epicentre, was severely affected despite its remote location. Due to this adverse situation, a preliminary assessment of the structural damage and geotechnical properties of Manavkuyu Neighbourhood of Bayraklı district was carried out by Erener et al. (2021). In this context, they analysed the spectral characteristics of strong ground motion and local field effects such as ground amplification, resonance and ground nonlinearity. In the paper, it is stated that the basin effect strongly contributes to ground amplification, but the researchers leave the evaluation of this to further studies.

Using the main shock and aftershock records from AFAD stations 3513 and 3514 located in Bayraklı district, the researchers first analysed the strong ground motion characteristics of the main shock. A preliminary assessment of local field effects, evaluation of the dominant period of the ground and ground amplification, and investigation of resonance phenomena were performed using the standard spectral ratio (SSR) (Borcherdt, 1970) and horizontal-vertical spectral ratio (HVSR) (Nakamura, 1989) methods. In addition, an effective stress-based site response analysis was performed on a soil profile representing the Manavkuyu District, thus providing an idea about the formation of excess pore water pressure and shear stress levels along the depth and at the surface.

At the end of the study, depending on the response acceleration spectra of the main shock, it was stated that significant response amplification occurred between the periods of 0.5 - 2.0 seconds, and considering the local ground conditions of Manakuyu District, the spectral accelerations in this period range were very close to the design spectra determined by TEC 1975. The dominant period of the ground was obtained as 1.54 seconds, which corresponds to this range, and therefore, it was mentioned that there is a high resonance potential for buildings with foundation periods in this range. It was calculated that if these buildings were designed according to TEC 1975, shear forces very close to the design values could occur during the main shock in addition to resonance effects.

Using ground response analyses and strong ground motion data on a typical soil profile in Manavkuyu District, shear stresses were evaluated in terms of nonlinear soil behaviour and it was observed that shear strain levels were between 10-4 - 10-3 in the surface layer and this may have caused the shear modulus to deteriorate. On the other hand, the presence of fine sandy layers and low mean effective stress values resulted in large shear deformations with high excess pore water pressures at depths of 20 to 30 metres.

Mihalić et al. (2011) presented a study to reveal the diversity of methodologies used in the preparation of seismic hazard maps and the basic principles of zoning for different purposes and at different scales. The researchers stated in their study that seismic codes are a prerequisite for determining seismic hazard zones and that guidelines and recommendations for seismic microzonation should be included in seismic codes. The paper presents two main approaches to earthquake damage reduction, one related to land use management and the other to the design and construction of individual buildings.

The article also said that the definition of seismic hazard zones necessitates the establishment of a framework at national or regional level that clearly defines (i) the position of seismic microzonation in construction practices and city planning; (ii) data collection, evaluation and zoning methodologies; and (iii) seismic regulations, including laws, codes and documents such as directives, advices and guidelines.

In conclusion, it was emphasised that microzonation is an effective instrument to reduce earthquake hazard through hazard-related land utilisation planning, but microzonation is not a substitute for current building and construction codes. It was stated by the researchers that seismic microzonation maps can guide on the necessary field-specific analyses based on the fact that seismic microzonation maps will not provide detailed hazard parameters at the specific construction site level. While large scales are used in microzonation maps for earthquake hazard estimation and site characterisation for any city, small scales are mostly used in national maps. Because of this difference, mismatches occur due to map scales. For this reason, the researchers stated that one of the main purposes of microzonation is to provide construction design data by substituting national macrozonation maps.

In the study by Ali Silahtar (2021), it was aimed to estimate the ground response of Isparta plain, which is located in the centre of one of the most important tectonic factors of Türkiye, using shear wave (Vs) and drilling results at 24 points. In the study area, which is characterised by ZC and ZD soil groups according to the soil classification criteria of the Turkish Building Earthquake Code (TBDY-2018), a 1-dimensional nonlinear ground reaction analysis approach was performed with DEEPSOIL software. Maximum ground acceleration (Pga) and spectral acceleration (Sa) distribution map for the study area was produced by Silahtar (2021) in the analysis performed using Mw:6.9 Irpinia strong ground motion record. In the study area, Pga values at the surface were found in the range of 0.28-0.41 g and maximum Sa values were found in the range of 0.77-1.82 g. The agreement between Pga and Vs30 in two sections perpendicular to each other in the basin was analysed by the researcher. With the data obtained at the end of the study, Silahtar (2021) stated that the effects of strong ground motion will increase significantly in the Çünür region where the city centre and new construction areas are dense.

In this study, 1-dimensional nonlinear ZTA (in time domain) values of the ground in the area covering Isparta city centre and its vicinity were calculated and a scenario was prepared based on the most effective 1914 Burdur earthquake over the study area considering the seismicity in the region. In this scenario earthquake model of the historical period, the strong ground motion was performed with the SturnoIrpinia station record of the 1980 Irpinia earthquake (Mw:6.9), which contains similar ground properties. In the scenario earthquake ZTA modelling, soil parameter variables were calculated from seismic and drilling data obtained at 24 points in total. The dynamic datas achieved from drilling and seismic (ReMi) parameters were utilised for Sa and Pga computations in DEEPSOIL software. Sa and Pga dispersion maps were produced to give an idea about the ground response in different parts of the study area. It was determined that the maximum Pga distribution at the surface varied between 0.25-0.42 g and some of these values were higher than the maximum ground acceleration value (0.3 g) indicated for the study area in the earthquake hazard map of Türkiye.

Silahtar (2021) stated that the maximum Sa values in the study area varied between 0.77-1.94 g. The highest Pga values in the basin were obtained in the vicinity of the city centre, Deregümü, Yakaören and Aliköy. In order to make sense of the high Sa values with the period of the building inventory in the study area, an empirical calculation was made and the building periods in the study area, which contains mostly 3-6 and 8-12 storey building stock (new settlements such as Çünür), were calculated as 0.36-0.6 s for 3-6 storeys and 0.75-1.03 s for 8-12 storeys, and it was emphasised by the researcher that a large part of the basin presents high hazard from the nonlinear 1D ZTA analysis when the building periods obtained accordingly are taken into consideration. In the study area where Vs30 distribution varies in between 280-480 m/s, it was determined that Vs30 values were limited to 360 m/s, which is the threshold value of ZC soil limit, in the basin dominated by alluvial stack, and the velocities increased relatively up to 480 m/s at the edges of the basin, and with these results, the basin was defined as ZC and ZD soil group according to TBDY-2018 soil classification criteria. In addition, on account of examine the relationship between local soil conditions and Pga values, the evaluation on two profiles in the basin revealed that Pga was in good agreement with Vs30 and the results showed the importance of local ground properties in the design of earthquake resilient structures. The researcher mentioned the necessity of conducting site-specific studies on a local scale before designing, even if general studies are carried out in the region, especially in city centres where the earthquake hazard is so high. As can be seen from the results of this investigation, the outcomes of the ZTA analyses performed at data collection points close to each other clearly reveal the difference in the effect of local ground conditions, especially between Mehmet Tönge and Çünür, which are located very close to each other in the study area. Silahtar (2021) stated that the parameters derived in this study can contribute to the design of seismic structures in and around Çünür, which is a new construction area especially in the northern part of the city centre, and recommended that special emphasis should be given to the design of new buildings in areas of the city where high Pga values are anticipated. On the other hand, he suggested that the results of the study should be taken into consideration in minimising the vulnerability risk of the currents building inventory in the catchment.

In the article prepared by Afacan and Güler (2019), the soil stratification and index properties of the layers were determined by examining 5 different boreholes belonging to Afyonkarahisar province located in the earthquake zone, the dynamic properties of the soils were modelled using these properties, and ground amplification analyses were performed by the researchers using earthquake records that occurred both in the region and in our country. As a consequence of the nonlinear analyses, the surface response was calculated and comparison with the response spectra proposed by TDBY for the region and its performance was evaluated.

In the article, it is stated that the analyses made depending on the local ground properties are of utmost significance for structures to be constructed in earthquake zones., and one of these site-specific analyses is ground amplification analyses. It is stated that ground amplification occurs due to the amplitude increases in earthquake waves in layers close to the surface and causes great damage to the structures. For the design of structures under dynamic loads, it is necessary to know the reactions that will occur on the surface due to earthquakes. For this purpose, ground amplification analyses were performed using 5 drilling logs and 3 earthquake records from Afyonkarahisar province, which has been subjected to major earthquakes in our country in the past periods, and its performance was evaluated by Afacan and Güler (2019) by comparing it with the spectrum curve obtained with TBDY 2018. As a consequence of the analyses; site-specific soil amplification analyses are of great importance for structures located in earthquake zones, layers with twice the maximum acceleration depending on the depth are observed in the soil profiles due to the earthquake, in the same way, when the sample profile is examined, the unit deformation is at maximum level between 13-17 m depending on the depth and the deformation levels along the layer vary depending on the properties of the soils, When the surface spectral behaviour were analysed as a result of the analysis. performed for a sample record, it was determined that there was amplification and damping at different periods, peak acceleration and peak spectral accelerations differed, and when all the analyses were evaluated together and compared with the spectrum envelope proposed by TBDY 2018, it was determined by the researchers that the seismic characteristics proposed by the new regulation for this region were successful to some extent and incomplete to some extent.

Afacan and Güler (2019) stated the main objective of this research is to provide an example for the user to work on safer designs by underlining the importance of site-specific non-linear realistic behaviour in addition to the spectral behaviour model given by the regulation for a region with a correctly determined soil profile.

In a comprehensive study by Sönmezer et al. (2019) a probabilistic seismic hazard analysis (PSHA) was performed on the dynamic ground properties of the city of Elazig, which is very close to the East Anatolian Fault Zone (EAFZ), which has a great devastating earthquake generating potential, and accordingly, the magnitude of the city was identified by the researchers as Mw=7.7 with a 10% probability of exceedance in 50 years. Acceleration spectra at bedrock grade were improved for the city using different damping effects and 1-dimensional equivalent linear ground reaction. The 16 earthquake motions recorded at bedrock level were analysed on the sample soil profile of the city using SHAKE2000 software. In the study where the average soil profile was estimated to obtain the local surface acceleration spectrum for the city of Elazığ by field tests at 125 different locations within the study area, the local surface acceleration spectra obtained from the analysis were then compared with the design spectra of the Turkish Earthquake Code for Buildings (TBDY 2018) and Eurocode-8 (EC8) in order to determine the difference between the code spectra and the local surface spectra, and in-situ geotechnical tests of standard penetration and seismic rupture were performed at different locations in the study area. The results obtained from the field tests were included in the field response analysis and the soil amplification factor, dominant soil period, PGA and spectral value were obtained for T = 0.2 and T = 1.0 s for the study area and contour maps of the study area were developed for these parameters. Accordingly, the results obtained from the present study indicate the need to determine the local surface spectrum of a region and to develop contour maps for important dynamic soil parameters in order to reduce the negative effects of earthquakes, as stated by Sönmezer et al. (2019). The results of the analysis show that structures with vibration periods higher than T = 1.0 s are subjected to lower spectral acceleration (Sa), whereas higher Sa values can be used for structures with vibration periods lower than T = 0.2 s.

At the end of the study, it was concluded that high- rise structures with high modal vibration ages are anticipated to be subordinated to lower spectral acceleration in all corridor of the megacity, while low- rise structures to be constructed in the eastern corridor of the megacity are prognosticated to be excited by moderate spectral acceleration, while these structures with low modal vibration ages will be affected by high spectral acceleration values in the western and southwestern corridor of the megacity. It's also stated by the experimenters that figure charts for important soil parameters can help to make dependable prognostications about which corridor of a region are suitable for low- rise or high- rise structures.

In the study conducted by Çabalar et al. (2019) using GIS-based computer software, the liquefaction potential of Kahramanmaraş, Türkiye was mapped. In this study, it was aimed to reveal the liquefaction potential of Kahramanmaraş province, which is located on the seismically active zones of the East Anatolian and Dead Sea Faults in central southern Türkiye. In this direction, both in-situ and laboratory geotechnical investigations were carried out.

A aggregate of 238 boreholes were drilled throughout the fiefdom to perform SPT tests and to determine the physical parcels of the soils(sieve analysis, Atterberg limits, soil bracket) grounded on these boreholes. The stratigraphic structure underpinning the studied area was determined by the experimenters to correspond of varying quantities of ground, complexion, clay and beach, and the ground water table situations in the study area were set up to vary between 0- 6 m and 15 m or further. Liquefaction eventuality was delved grounded on SPT results and a academic earthquake of magnitude7.5. Türkiye has endured ferocious construction exertion in largely seismically prone areas and a corresponding rapid-fire population growth in civic agreements. In the paper, it's stated that since seismic hazard sensitive civic planning and seismic resistant construction isn't the top precedence in Türkiye, it has lately been in the process of renewing its legal structure in order to reduce the goods of possible seismic hazards.

Çabalar et al. (2019) stated in the composition that Kahramanmaraş is located in a region with high liquefaction eventuality and should be addressed in terms of civic planning and threat operation. By using the liquefaction implicit charts produced for the study area, it was suggested that the pitfalls should be planned and estimated effectively, but with the earthquake that passed on 06.02.2023, it was seen by all of us that the authorities were late in this regard and the necessary measures couldn't be taken.

An empirical correlation was produced by Irsyam et al. (2019) using standard penetration pulse count and S-wave velocity for practical purposes in point characterisation based on original data as a case study with Jakarta, Indonesia selected as the study area. 1D point response analysis was performed in 5745 simulations to estimate the inflexibility of implicit earthquake shaking at the ground face. The field exaggeration values were also estimated by dividing the spectral acceleration (Sa) at the ground face by the Sa at the gemstone ledge. Plots of Sa exaggeration values at applicable depth intervals of the bedrock face subcaste were assigned. The results indicated that the estimated point exaggeration values considering the original depth of the bedrock face subcaste are generally lower than the Sa exaggeration values attained from the Indonesian seismic structure law, especially for the soft soil point class, which tends to regress the average exaggeration at lower situations.

The empirical correlation between N and Vs was developed for the Jakarta region and applied to the point bracket, and the fit of the correlation was by correlations. The correlation appears to shift the point bracket chart of the Jakarta region to a more severe point class. For the original point conditions of Jakarta, the result shows that the point exaggeration values estimated by considering the original depth of the bedrock face subcaste are generally lower compared to those according to the current law. The trend shows that the modification value decreases as the depth of the bedrock face subcaste increases. This study is indicated to give a better point response to dynamic excitation for spots with deep ground face layers similar as Jakarta.

In the study prepared by Civelekler et al. (2018), it is stated that the differentiation of the stratification of soils affects the way and magnitude of the transfer of earthquake ground stir to the structure and thus the dynamic loads to be applied to the structure. In the study, it is stated that the aim of the study is to obtain soil amplification values for alluvial soil covering the city centre of Eskişehir by using one dimensional equivalent linear analysis method, which has not been done for the region in previous studies, and to draw location-based maps with GIS techniques in order to present these values for the benefit of users, as well as to easily take into account the amplification values that need to be taken into account depending on the location for the region with the mapping made.

In order to define the effect of the ground layers in the study area on the behaviour of the ground surface under earthquake loads, ground amplification analyses were carried out within the scope of local seismic hazard studies and in these analyses, the stages of determining the soil engineering properties, selecting acceleration-time records and performing ground amplification analyses were followed (Ansal et al. , 2011).

The researchers stated that in order to perform the analyses, in addition to defining the index properties of the soil, it is necessary to define the dynamic properties of the soil, and this requires the correct modelling of the shear modulus reduction of the materials at different shear unit deformation levels, and the relations of Darendeli (2001) were used to define the shear modulus reduction curves of sand and clay layers in their studies.

In this study, shear wave velocity values attained by drilling and seismic studies in the ground of Eskisehir city centre were determined by using real methods that are fully representative of the ground, and the ground amplification studies carried out so far for the study area were obtained by Civelekler et al. (2018), by determining the dynamic properties of the ground by the equivalent linear analysis method without the need for empirical methods with the studies carried out using empirical methods proposed for other soils.

In the article stating that the study pioneered the approach of determining the site-specific dynamic properties of the soil specified in TBDY 2018, section 16, it was mentioned that the microzonation maps prepared according to various variables using Geographic Information Systems provide great benefits, especially in determining new settlement areas and revealing the soil properties of existing settlement areas, and that the prepared maps reveal the general structure of the study area, saving time and cost as well as information about the seismicity of the region for researchers working on this subject. For this reason, it is stated by the researchers in the article that the amplification map obtained as a result of this study provides data that can be used for the construction of safe structures within the scope of pre-disaster risk identification and mitigation studies.

Puri et al. (2018) used the DEEPSOIL software to perform a detailed 1D original direct ripple propagation cast to estimate the effects of the original ground environment on earthquake ground motions. Aiming that the solutions will be conducive for structural contrivers and civic itineraries and can be utilized as a leading instrument for performing further dynamic analyses, the experimenters chose the state of Hayrana in North India with its metropolis Chandigarh as the study area. Hayrana is a landlocked agreement. It has been stated by the experimenters that the region is covered by three

Seismic Zones 2, 3 and 4 according to the regulations to which the region is combined. This shows that the region is open to low and medium harm threat from earthquakes.

In this study, the researchers utilised various agencies and geotechnical consultants such as Haryana Urban Development Authority (HUDA), Public Works Department (PWD), Northern Railways (NR), Delhi Metro Rail Corporation (DMRC), Nuclear Power Corporation of India Limited (NPCIL), Rail Vikas Nigam Limited (RVNL). The developed geotechnical database contains information for 1053 different locations covering almost every region up to 50 m depth in the State of Haryana.

The researchers defined the procedure as 4 steps; collecting data, modelling the collected data for computer programmes, running the programme and finalising the results. In this study, they used DEEPSOIL software to determine the goods of original ground circumscriptions on earthquake ground movements, performed detailed 1D original direct surge propagation breakdown and estimated the results. During the study period, earthquake response analyses were carried out for various sites in Hayrana and it was observed that the amplification factor (AF) for PGA for Hayrana province ranged from 0.702 to 2.339. These values indicate that the soils in Hayrana province are capable of amplifying earthquake ground movements.

At the end of the study, the researchers observed that PGA values reached an amplification value of 2.339 at the nuclear power plant site. It is also stated in the article that in some areas, the PGA value reaches high stress and high amplification values in the top 9 m of the ground, and in these areas, the PGA value is more than 2 times higher. It is also stated by the researchers that the shear stress increases from 0.1% to 0.5% in this section and this value is a high strain value. At the end of the article, the researchers stated that during an earthquake, grounds at more profound may also be subject to subsidence or earthquake-induced liquefaction if circumscriptions are convenient. In addition, the comeback spectra and face acceleration period chronicles acquired for the study area can be utilized for dynamic analysis of significant architectures in the country.

Akın et al. (2015) revealed the dynamic soil properties of Van Yüzüncü Yıl University (YYÜ) campus area with the findings obtained from drilling studies and geophysical methods. Within the scope of the field studies carried out, soil conditions together with liquefaction and ground amplification factors were revealed and the campus area was examined in this context. As a result of all these studies, a settlement suitability assessment was made by the researchers for the campus area in order to guide future planning. After the 23 October 2011 Van-Tabanlı earthquake (Mw=7. 2), retrofitting and renovation works were started in the damaged buildings in the campus area of Yüzüncü Yıl University, as well as in Van-Centre and Erciş district, which were most affected by the earthquake. Since it is important to reveal the ground features of the campus site in terms of reorganisation of the campus area and determination of the locations of the new buildings to be constructed, a study was carried out in order to reveal the ground features of Yüzüncü Yıl University campus area in suitability accompanied by the microzonation principles and to reveal the dynamic properties of the campus area with the help of Geographical Information System. (GIS).

As a result of the study, the settlement suitability map prepared for the YYU campus area indicated that detailed geotechnical surveys (drilling, geophysics, etc.) should be carried out for all new structures to be built, since the soils in the campus show a heterogeneous structure and can change in short distances. On the other hand, the researchers suggested that detailed fault investigations should be carried out for possible faults that may be parallel/near parallel to the Van fault passing near the northern border due to the YYU campus area. In the map of suitability for settlement, it was determined that the rate of suitability for settlement decreases as you approach the shore of Lake Van, while the rate of suitability for settlement increases as you move northwards in the campus area. When approaching the area close to the Van fault, it is recommended to avoid settlement in and around the fault by accepting the fault fracture trace as a certain buffer zone.

Palutoğlu (2014), in his doctoral thesis study, chose Elazığ city centre and its immediate surroundings as the subject, and aimed to reveal the detailed structural geological features of the study area and to reveal the engineering properties of the city centre such as soil properties, its behaviour during earthquakes and the effects of possible earthquakes on the city centre in detail.

At the end of the study, the maximum thickness of the basin fill in the city center of Elazığ was determined as approximately 500-550 m. According to this result and considering the measurements made, Palutoğlu (2014) stated in his thesis that the place where the thickness of the basin fill is the highest in the town center of Elazığ is the territory called Sürsürü Dis. located around Mount Meryem, and therefore, in the region where the thickness of the basin fill is the highest, adverse effects may occur in this section during a possible earthquake, and Sürsürü Mah. is in the first three of the regions most affected by the Elazığ-Sivrice earthquake dated 24. January.2020.

Again, at the end of the study, it was determined that when the largest earthquake occurs in the investigation terrain, the magnitude of the earthquake will be IX, therefore its equivalent on the magnitude scale; Type C; many buildings (50%) may have heavy damage and a few (5%) may have collapse, Type B; many (50%) buildings (50%) may have collapse and a few (5%) may have heavy collapse, Type A; many (50%) buildings (50%) may have heavy collapse. The building types here are; Type A; village type houses made of cut stone, rubble and adobe with mud mortar, Type B; brick, briquette, cut stone buildings with cement mortar, half-timbered buildings and prefabricated buildings, Type C; reinforced concrete buildings, well constructed half-timbered buildings. Damage percentages are as follows; a. A little; about 5%, b. A lot; about 50%, c. A lot; about 75%. The classification of damages in buildings is as follows; I. degree (light damage); Fine plaster fractures occur and small parts of cataplasm fall off. Grade II(average damage); little fractures in the barriers, big parts of cataplasm fall off. Grade III (heavy damage); Big and deep fractures in the barriers. Many of the shafts fall down. IV. degree (catastrophic); Walls are breached, parts of buildings may collapse, buildings are separated from their joints. Infill walls of buildings collapse. Grade V (total damage; heavy destruction): Entire buildings collapse.

It is reported by Palutoğlu (2014) that the soil on which the city center of Elazığ is located shows all the negative characteristics that it may show during an earthquake. The magnitudes of V_p/V_s, arias intensity and particle velocity indicate the possibility of soil liquefaction. In other words, it is reported in the study that in a possible earthquake, a structure located in Elazığ city center will be affected by ground amplification, ground liquefaction, ground resonance and high earthquake shear force. In the same study, Palutoğlu suggested that a modern city plan in which soil properties will be prioritized should be prepared urgently, buildings in the first and second degree earthquake risk areas should be reduced and green areas, wide roads and boulevards, parks and sports areas etc. should be constructed and the height of the buildings should not be more than half of the road width in such grounds.

In the paper prepared by Iyisan and Haşal (2011), a model with a uniform geometry consisting of a plain and a hill was selected to investigate the effect of local soil properties on ground amplification. In this model, one- and two-dimensional dynamic analyses were performed using six bedrock earthquakes with different frequency contents for the case where the upper soil layer in the soil section in the plain region is high plasticity clay and silty sand. The researchers obtained acceleration time histories and acceleration spectra for different earthquakes at different points on the surface in the plain and hill region, the changes of these values depending on the distance from the bedrock outcrop boundary at the edge were examined, and the results of one and two dimensional dynamic analyses were compared.

As a result of the research, the researchers stated that soil growth is influenced by regional conditions like bedrock depth, thickness and dynamic characteristics of soil stratas, side irregularity of soil strata and topographical characteristics. In order to investigate the effect of local conditions on soil growth, they performed one and two dimensional analyses with an equivalent linear material model on a geometry consisting of plain and hill regions. On account of studying the effect of ground type on dynamic attitude, Iyisan and Haşal (2011) considered the top soil layer in the plain region as high plasticity clay and silty sand separately, and six bedrock earthquakes with different frequency contents were used in the analyses and the results obtained were compared. It is observed that the accelerations from the bedrock level are doubled on average at the ground surface if the top layer is sand, the amplifications increase approximately 5 times if the top layer is clay, and the spectral amplification increases up to 6 values in the hill section with sloping topography. In case the top layer is clay, the spectral acceleration ratio calculated in the sections located on the projection of the surface of the area where the bedrock slope reaches the bottom of the plain is found to be the largest value at high frequencies, and the difference between the one and two dimensional analysis results decreases at high periods with increasing distance towards the centre of the plain. If the top layer is sand, similar behaviours are observed in different parts of the surface at high periods, but an increase in spectral acceleration rates at low periods in the region of the projection of the bedrock on the surface is reported. In addition to bedrock acceleration, the variation of local soil conditions and dynamic properties depending on soil type did not play a significant role in the dynamic behaviour. It has been reported by the researchers that the spectral amplifications are less in sand soils where stiffness reduction starts at smaller shear deformations than in high plasticity clays where stiffness reduction starts at larger deformations.

Güzel (2009), in his thesis study, selected the North Adana region and in this thesis, it was aimed to create safe new settlement areas by processing the disaster risks in the areas to be opened to settlement and the disaster hazards in the established sites into maps that can be used at local scale and to ensure the planning of applications for mitigation in case of disaster in existing new settlement areas.

Consequently the field studies, Güzel (2009) realised microzonation of the study territory and classified the soil of Handere in general with different lithological properties. He also determined the liquid limit, plastic limit and water content index properties of the soil. In the thesis study, it was determined that there are landslides developed at different times on the slopes where there are one-, two- and three-storey houses, and the vertical thickness of the gliding bulk is between 5.5 and 7 meters in the sections where these landslides are most common, with drilling and geophysical applications.

In this study, the advantages and disadvantages of geological, geophysical, geotechnical studies and data generation applications for microzonation of the Investigation area in terms of their effective applicability, ability to define soil properties and cost features were observed by Güzel (2009); in the determination of strength properties due to different proportions of carbonate structure in formations at different locations, drilling and in-situ tests (misleading lithologic appearance and SPT-N) numbers due to dissolution and washing of the carbonate component in water during drilling application, due to the intense heterogeneity in the distribution of the unit, which can be pointwise, The data obtained from the seismic velocities measured by seismic application has been more effective and more decisive in determining the strength properties of this unit (both in terms of being more unique in terms of the fact that the application can be done without disturbing the nature of the ground, and in terms of being fast and economical in terms of profile-based rather than point-based).

In his study, Güzel (2009) stated that although microzonation studies can be carried out within the framework of certain principles and guidelines, when looking at the practices both in the world and in Türkiye, the required criteria may be different for different application areas or the order of priority in defining the criteria may change; In the microzonation of an area where groundwater is high and fine alluvial soils dominate, the primary microzonation criterion is liquefaction, whereas in the case of fine-grained discrete soils located on high slopes, as in this study, the slope instability criterion of microzonation gains importance. For an area with active tectonism and faulting, the definition of the faulting criterion of microzonation will gain priority, however, there are also environmental and soil conditions where many or all of the known microzonation criteria are necessary and prioritized, in more general terms, it is emphasized in the study that in the selection of microzonation criteria for a particular area, the type of construction planned for this area, environmental climatic conditions, local soil conditions, disaster status and seismicity of the territory should be taken into consideration.

Microzonation applications are a step further in that they include data such as dynamic data analysis (such as amplification criteria), earthquake hazard analysis and risk calculations, which are the main hazards especially in static construction, in addition to the contents of classical surveys prepared for settlement suitability or as a basis for zoning plans, In the thesis prepared by Güzel (2009), it is concluded that microzonation studies are necessary applications for settled and to be settled areas in terms of reducing earthquake damages, especially in societies that have to live with earthquakes.

In their study, Topal and Akın (2009) aimed to prepare a seismic microzonation map of the study area of Erba district of Tokat for urban planning and to reveal the soil conditions by one-dimensional dynamic behaviour analysis. The amplification values determined by dynamic behavior analyses indicate that the ground units in the study area are generally solid and, in addition, liquefaction potential for the study area and post-liquefaction effects such as settlement and lateral spreading were also determined by Topal and Akın (2009), these parameters were taken into consideration for the preparation of the final microzonation map of the study territory. The generated layers were evaluated using Multi Criteria Decision Analysis (MDAA). Two different analyses, namely Simple Weighted Sum (BAT) and Analytical Staged System (AAS), were applied on the basis of Geographic Information System (GIS). The BAT and AAS based maps were compared to determine the final seismic microzonation map. As a result, the map prepared based on the AAS method is recommended as the final seismic microzonation map for Erbaa.

At the end of the study, Topla and Akın concluded that the settlement of Erbaa within the active CAFZ is located on Pliocene sediments consisting of uncemented and poorly cemented gravel, sand and clay and alluvium consisting of gravel, sand, silt and clay brought by the Kelkit River, which varies in lateral-vertical direction, that depth-dependent V_S velocities can be determined more accurately by using the SPT-uphole method, and with respect to the consequences of the deterministic seismic hazard analysis where the distance to the fault is taken into account, The alluvium close to the fault is more susceptible to earthquake-related hazards, the alluvial area to the northwest of the Erbaa settlement area is more susceptible to earthquake-related deformations (settlement and lateral spreading due to liquefaction), damage to structures may occur especially on the banks of the Kelkit River, and less earthquake-related damage is expected in the northeast and south of the settlement area. In the study area, where different methods give different results and 2-3 times amplification is expected in places, the amount of amplification also changes in different periods, and according to the multi-layer overlay analysis performed in GIS environment using Simple Weighted Sum (BAT) and Analytical Progressive System (AAS), AAS method gives a better and usable seismic microzonation map for the study territory. As per these results, Topal and Akın (2009) stated that the seismic microzonation map prepared by AAS method should be used in the long term planning of Erbaa settlement and the fault zone and 1st degree protected area indicated on this map should be closed to settlement.

In their paper, Sitharam and Anbazhagan (2008) aimed to develop a seismotechnical map for a microzonation area covering an area of 350 km radius around Banglore, India, using the seismicity and seismotechnical factors of the region.

Sitharam and Anbazhagan (2008) used deterministic and probabilistic approaches for seismic hazard analysis. At 653 locations, maps of synthetic ground motion, recurrence relationship and highest ground acceleration at rock level were created. The researchers performed a exhaustived site description using standard penetration test (SPT) "N" ratings and geophysical parameter and drilling, and used Geographical Information System (GIS) to create a basemap and 3D subsurface drilling model for the study area. At 58 locations, they used the multichannel analysis of surface waves (MASW) method to generate a one-dimensional shear wave velocity profile and a two-dimensional profile at 20 locations. They used the shear wave velocities to predict the equivalent slip velocity at every 5 m intervals up to a depth of 30 m in the study territory.

Sitharam and Anbazgahan (2008) in their study on seismic activity of India, intra-plate and destructive earthquakes throughout the frontiers of the Indo-Australian Plate and Eurasian Plate, India's past history of earthquakes and lately devastating earthquakes in India; Killari (1993), Jabalpur (1997), Bhuj (2001), Sumatra (2004) and Indo-Pakistan (2005) show that the region is still facing the threat of earthquakes. It is mentioned in the article that many researchers have discussed the intraplate earthquakes and seismicity of South India. Intraplate earthquakes and seismicity of South India have been discussed by many researchers. As part of the national level microzonation program in 63 cities of India, the Government's Department of Science and Technology has launched a microzonation study as part of the preliminary preparation process for earthquake mitigation, hazard self-assessment and assessment.

At the end of the paper, Sitharam and Anbazgahan (2008) suggest that in shallow areas with engineering rock at a depth of 30 m, it is not appropriate to apply the average soil class and in such areas it is suggested to get the mean shear wave velocity to the deepest part of the cover thickness (engineering rock).

This paper presents a brief of the seismic microzonation of Bangalore with a simple conceptional and also generates hazard maps using both deterministic and probabilistic methods. The probabilistic work generates the spectral acceleration map, which is a key element, and it is further recommended to generate spectral acceleration maps at the surface level utilising the probabilistic method. As recommended by Sitharam and Anbazgahan (2008) in the paper, a probabilistic hazard map for a given rotation period would be more beneficial for vulnerability and hazard analysis.

It was noted that although various hazard list maps have been produced for Indian cities, it was noted that these maps were advanced by taking into account different number of themes, weights and rankings. Since there is no universal equivalence in the hazard index values, therefore the identification of the number of themes, their weights and the identification of their ranking should be suggested in the near future, as a preliminary stage, the importance of taking into account various themes to create hazard maps has been indicated by the researchers.

Palutoğlu and Tanyolu (2006), in their article, aimed to determine the 1/5000 scale geological map of the settlement region (Elazığ) and the earthquake amplification coefficients of the rock units forming the ground, in other words, to reveal the earthquake risk of the region. Palutoğlu and Tanyolu (2006), who utilized old and new cores during this study, also obtained the information of some regions by resistivity method and utilized the SPT values of the borings in the construction of the soil liquefaction map. As a result, the geological map of the provincial center is divided into three regions as "very risky", "medium" and "less risky" in terms of earthquake risk and these regions are shown on the map.

A 1/5000 scale soil liquefaction map was obtained by calculating the S-wave velocity values at the drilling points from the SPT values of 512 borings made between 1999-2004. In this map, the soil liquefaction probability is divided into three zones as high (0-200 m/s), medium (200-300 m/s) and low or absent (>300 m/s). Although most of the hazardous zones overlap in the geologic map and soil liquefaction maps, Palutoğlu and Tanyolu (2006) found that the zone of high risk of soil liquefaction is slightly smaller than in the geologic map. Palutoğlu and Tanyolu (2006) attributed this difference to the groundwater level and the fact that different people performed the SPT tests, and stated that since fine-grained alluvial soils without soil liquefaction are sufficiently risky in earthquakes, it would be correct to take the geological map as a basis in earthquake-related evaluations and planning.

In the study area, the highest earthquake risk is found in silty clay with an earthquake amplification coefficient of 13-18 and in sandy gravelly clays with a amplification coefficient of 7-12. The soil coefficients obtained in this study area can be expected to significantly increase the extent of damage in a possible earthquake.

In addition to being the most densely populated area, the settlement area of Elazığ City Center is on the first degree earthquake risky ground. In addition, Palutoğlu and Tanyolu (2006) stated in their article that the high-rise buildings, narrow streets and alleys in the region may increase the extent of damage and suggested that an up-to-date city plan should be prepared urgently.

3. MATERIAL AND METHODS

3.1. General Information About the Study Area

Elazığ town is located in the southwest of the Eastern Anatolia Region, in the Upper Euphrates Region. With a total face area of 9151 km^2 and constituting1.2 of Türkiye's home, the city is located between 40º 21 and 38º 30 east longitudes and 38º 17 and 39º 11 north authorizations. Within this framework, Elazığ province, which roughly resembles a rectangle in shape, has a length of approximately 150 km in the D-W direction and a width of approximately 65 km in the N-S direction. The city is encirceled by Bingöl from the east, Tunceli from the north via Keban Dam Lake, Malatya from the west and southwest via Karakaya Dam Lake, and Diyarbakır from the south (URL4).

Elazığ is surrounded by the western extensions of the Southeastern Taurus Mountains to the east, west and south. The Southeastern Taurus Mountains extend eastward within the borders of Malatya and pass through Elazığ. They continue in curves towards the south of Lake Van and leave the borders of our country. The highest point of these mountains is Hasan Mountains (2118 m) in the west of the province (URL4).

Elazig province is the continuation of the city of Harput, founded in 4000 BC, in the plain. The history of Elazığ, a new settlement center, is studied by historians together with the history of the city of Harput, of which it is a continuation. Indeed; Harput, which is only 5 km away from today's city center, is the first settlement of Elazığ with its 4000 years of history dating back to 2000 BC according to written sources. Historical sources state that the first inhabitants of Harput were "Hurris". It is known that the Hurris, whose thesis that they originated from Asia is generally accepted, were in contact with the Hittites and Assyrians who also settled in the region. The fact that Harput is referred to as "Isuva" in the written sources found in Boğazköy, the capital of the Hittites, confirms this information. The place of the Urartians, who established a state in Eastern Anatolia in the 9th century BC, in the history of Elazığ can be observed from the traces of the Urartian Period carried by Harput Castle. There is no doubt that the most important battle in Harput's becoming a Turkish homeland after the Great Seljuk Empire's sovereignty shifted to Anatolia was the Battle of Malazgirt. As a matter of fact, Harput and its surroundings were captured by the Turks after the Battle of Malazgirt, and the Çubukoğulları Principality was established in the region under the Great Seljuk Empire (1085). This place, which remained only as a fortified castle until the capture of Kharpert by the Turks, became a city that grew with the Turks. The Çubukoğulları Principality did not last long and then the Artukoğulları period began in 1110. After a while, an independent principality known as Harput Artuqids was established. Harput was captured by the Mongols in 1230, and from 1234 it came under the rule of the Anatolian Seljuk Empire. In 1507, Harput was captured by the Safavids, and in 1514 it came under Ottoman rule with the Battle of Chaldiran. Elazığ, which was moved to its present settlement called Mezra in 1834, was named Ma'mûretü'l-Azîz Vilâyeti in 1862 with the proposal of Governor İsmail Pasha, who was appointed here during the reign of Ahmet İzzet Pasha of Kütahyalı in the fifth year of Sultan Abdülaziz's accession to the throne. However, since it was difficult to pronounce, it was simply called el-Azîz among the people. The name of Elaziz was changed to Elazığ with the decree dated 10 December 1937 and no.7806 promulgated in the Official Gazette dated 17 December 1937 and no. 3785 (URL5).

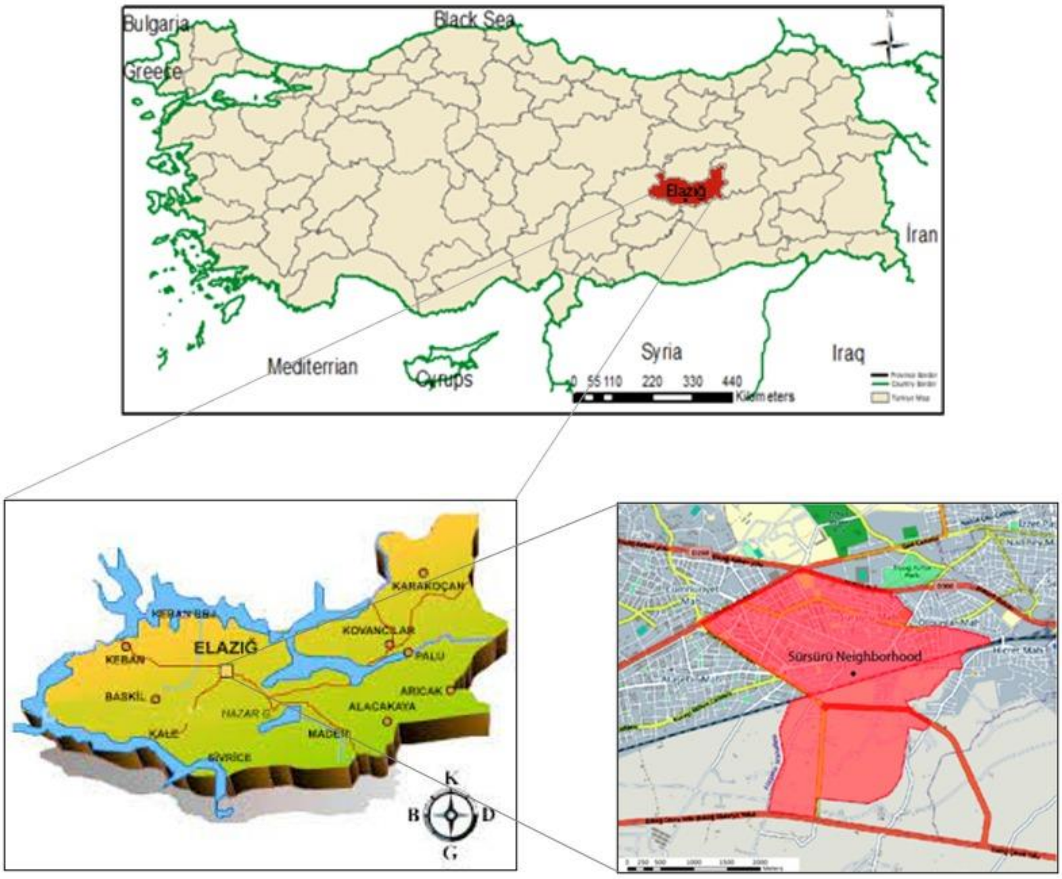


Figure 3.1. Location map showing the Sürsürü Neighborhood of Elazığ in Türkiye

3.2. Geology of the Study Area

The units seen in and around Elazığ province, in which the study territory is situated are, from old to young; Keban Metamorphites composed of Permo Triassic old crystallised limestones; Elazig Magmatites composed of Cenonian old granite, granodiorite, basalt, basaltic pillow lava, andesite and dacite dykes and volcanosedimentary rocks; Harami Formation composed of Upper Maestrihtian aged massive limestones, Kırkgeçit Formation composed of Middle Eocene-Upper Oligocene old pebbles, sandstones, marls and limestones; Maden Complex composed of sedimentary rocks such as mudstone, sandstone, claystone and igneous rocks like basalt, andesite and diabase; Karabakır Formation composed of Upper Miocene-Lower Pliocene aged tuff, agglomerate, basaltic lava and laterally transitional lacustrine limestones (Paluoğlu, 2014). Figure 3.4 shows these layers on the map drawn by Palutoğlu in 2014.

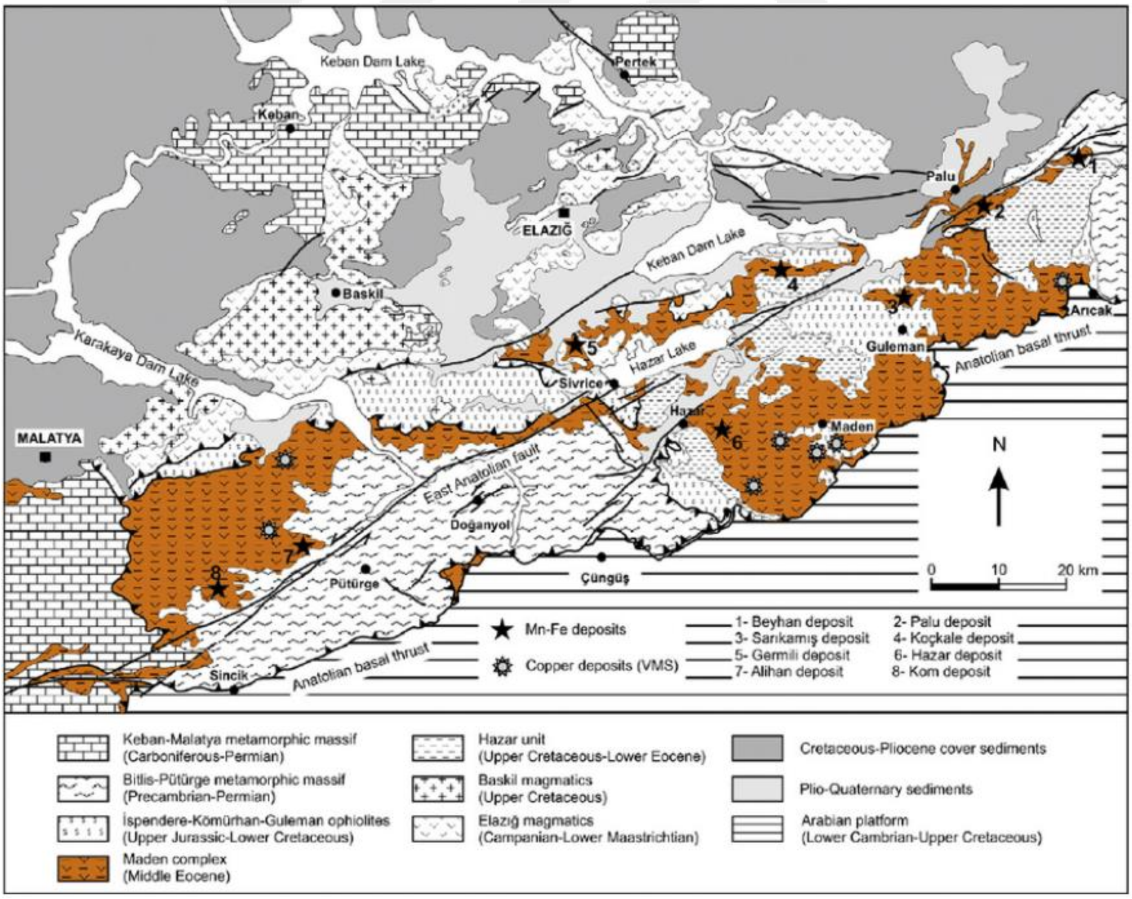


Figure 3.2. Regional geological map of the Elazığ - Malatya region. Taken from Mineral Research and Exploration (MTA, 2002)

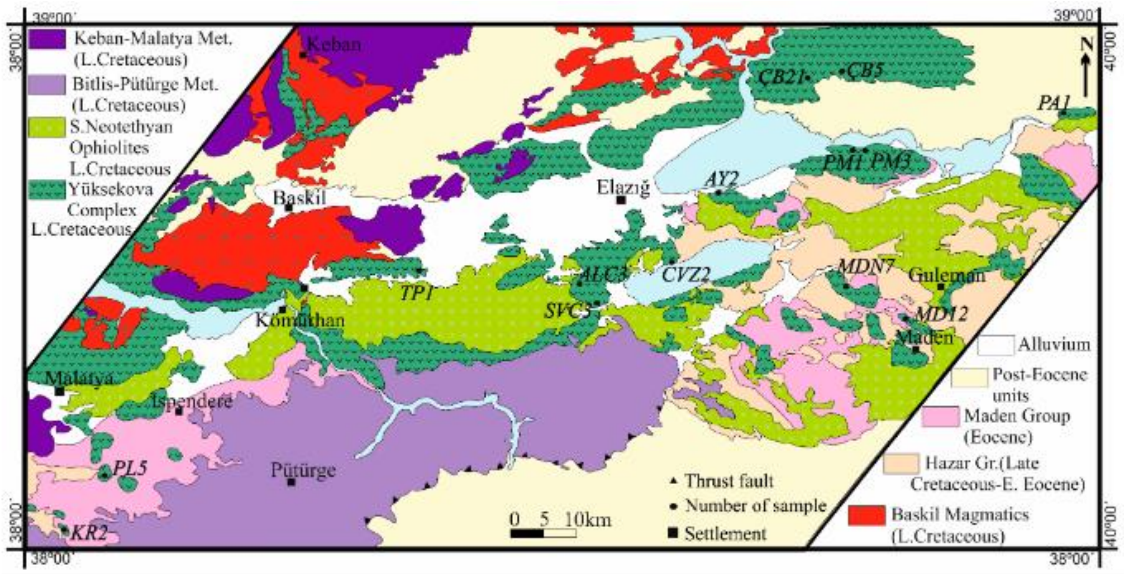


Figure 3.3. Geological map of the Elazığ region with the study area (MTA, 2011)

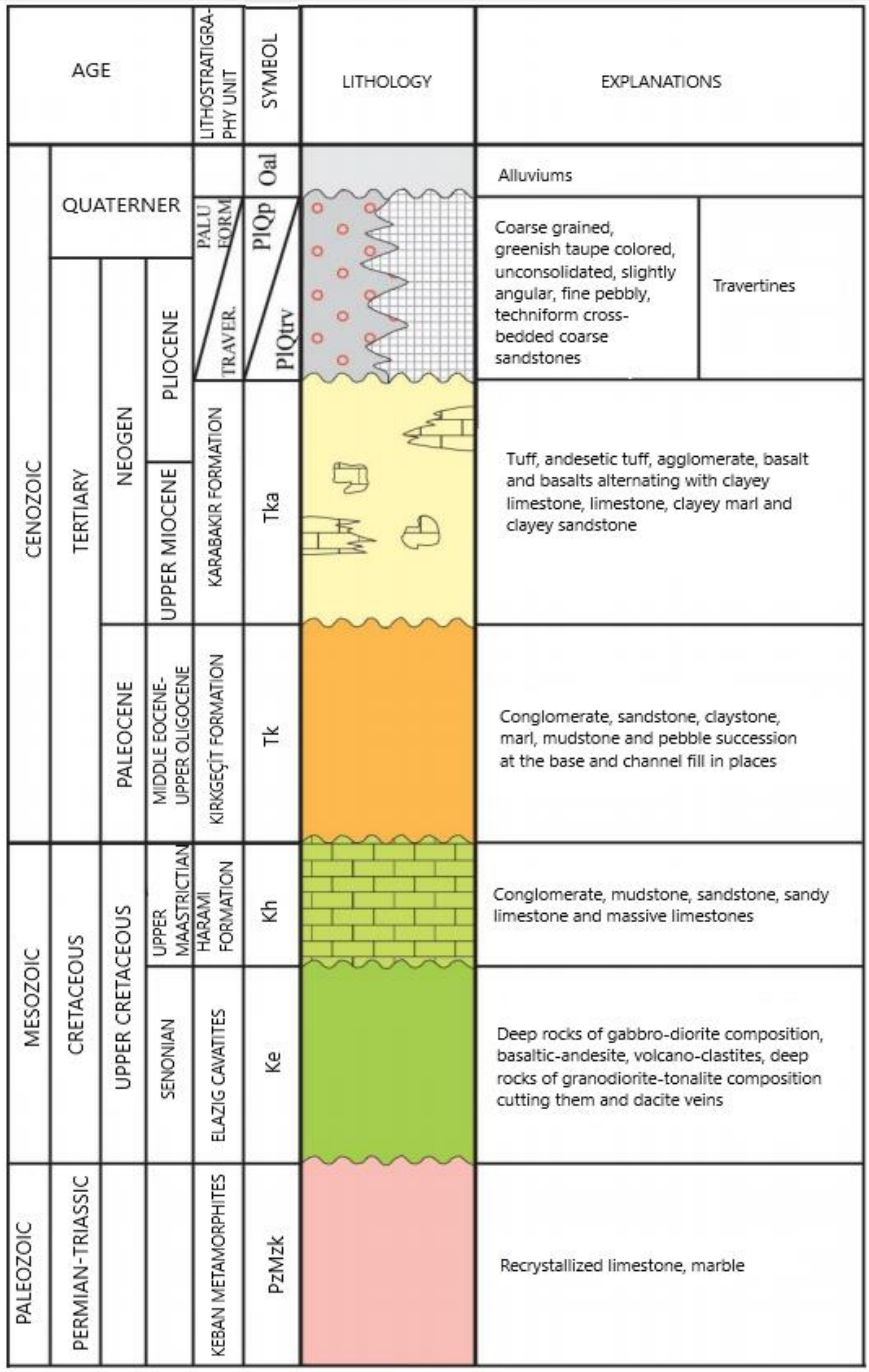


Figure 3.4. Generalized Stratigraphic Section of the Investigation Area and Surroundings (Palutoğlu, 2014)

3.2.1 Keban Metamorphites

The unit is surfaced in two different sections; within the region among Abdullahpaşa-Sarıçubuk neighbourhoods and Allahuekber Hill and on the slopes of Meryem Mountain southwest of Sürsürü neighbourhood (Palutoğlu, 2014).

The Keban Metamorphites (Permo-Triassic; PzMzk) consist of recrystallised limestone-alkschist, marble, metaconglomerate-alk phyllites, although in the study region they are emblematized by recrystallised limestones. The thick carbonate sediments here were deposited on a calm and shallow marine platform from the Early Permian to the Late Triassic. The Keban Metamorphites, consisting of shelf-type carbonates and clasts deposited in the Permo-Triassic, are mainly low-grade green shale facies, although the amphibolite facies is occasionally observed (Palutoğlu, 2014).

3.2.2 Elazig Magmatites

This unit, which was named as Yüksekova Complex by Perinçek and surfaced extensively between Hakkâri and Elbistan, was named as Elazığ Magmatites (Senonian) by determining its features in the vicinity of Elazığ. (Palutoğlu, 2014)

Elazig Magmatites were divided into two as igneous rocks (Ke_2) and volcano-sedimentary rocks (Ke_1). The igneous rocks (Ke_2) surface from the west of Harput, north of Fevzi Çakmak District, Esentepe District, Safran District, north of Fırat University, Cumhuriyet District, around Abdullahpaşa, 1 km east of Şahinkaya Village, Yeniköy District, Yadigâr District. The volcano-sedimentary unit (Ke_1) surfaces around Keklik Tepe, Eskibeyyurdu, east of Karşıyaka District and south of Çatalçeşme District. (Palutoğlu, 2014)

Elazığ Magmatites, which are not found in the central settlement area of Elazığ city, are tectonically overlain by Keban Metamorphites, Harami Formation conformably, Kırkgeçit Formation angularly unconformably and Karabakır Formation unconformably. Elazığ Magmatites are lithologically contained of gabbro- diorites at the bottom, basaltic- andesitic stormy jewels and volcanoclastics above them and granodiorite- tonalite and dacite dykes breaking down all of it. Elazig Magmatites are mapped in two separate units:

Ke_1: Volcano-sedimentary, volcanic sandstone and red mudstone

Ke_2: Basalts, basaltic pillow lavas and andesites and dacite dykes cutting them

According to Perinçek and Özkaya, it is composed entirely of rocks representing island arc or oceanic crustal development on continental crust or continental crustal extension.

According to Bingöl; it is a product of an island arc developed on a north-dipping subduction zone with calc-alkaline characteristics. The age of the Elazig Magmatites is Campanian-Maestrichtian according to the fossils identified by Perinçek. According to the radiometric determination of the samples taken by Yazgan from the vicinity of Baskil; the age of the deep rocks is Coniacian-Santonian, the age of the semi-deep and surface rocks is Campanian, and according to the paleontological determinations of Aksoy in the vicinity of Van; it is Campanian-Lower Maestrihtian (Palutoğlu, 2014).

3.2.3 Harami Formation

It surfaces as islets of a couple of hundred frames meters in the north, south and east of Harput. The unit overlies the Elazig Magmatites and is unconformably overlain by the Kırkgeçit Formation.

This unit, which is mostly consisted of massive limestones, is composed of lensy red conglomerate and sandstone at the base and sandy limestone and massive limestones at lower levels in the vicinity of Harput. In the study area, massive limestones are about 20 m thick and are in the form of prominent hills in the topography due to their high resistance to abrasion. They are white and beige in color. According to Turan and Bingöl, the occurrence conditions are shallow, clear, not very common and reefal in places. According to the researchers, the Harami Formation (Upper Maestrihtian; Kh) was precipitated in a small and shallow basin in the Meastrihtian. The red conglomerates and sandstones at the ground are territorial sediments with fan delta type. The sandy limestones and limestones on top of these are carbonate accumulations precipitated in the shoaly sea. As per the palaeontological results, they are Maestrichtian or elderly (Palutoğlu, 2014).

3.2.4 Kırkgeçit Formation

The widespread Kırkgeçit Formation (Middle Eocene-Upper Oligocene; Tk1, Tk2, Tk3) extending to Van was mapped in three different lithologies in the study area. Tk_1; Sandstone-marn member, surfaces north, northeast and northwest of Virane District. Tk_2; Pebble-sandstone member surfaces around Sarıçubuk and Şahinkaya Villages and Körpınar District, north of Cumhuriyet and Zafran Districts, north and northeast of Harput, and Tk_3; Marl member surfaces north of Akyazı Ridge and near south and about 1 km north of Virane District. In the study area, the Kırkgeçit Formation unconformably blankets the Keban Metamorphites, Elazığ Magmatites and Harami Formation at the base. Karabakir Formation is also unconformably overlying it (Palutoğlu, 2014).

3.2.5. Karabakır Formation

Karabakır Formation (Upper Miocene-Lower Pliocene; Tkb1, Tkb2, Tkb3) is categorised in three units as volcanites (Tkb_1), limestone (Tkb_2) and pebble-sandstone (Tkb_3). Volcanites are exposed approximately one km east of Yeniköy and west of Yadigâr District. Limestone member is observed around Rızvan Tepe and Baz Tepe and west of Doğukent, Salıbaba and Çatalçeşme neighborhoods. The pebble-sandstone member is found in the vicinity of Yadigar District, close north and northeast of Yeniköy District. Karabakır Formation unconformably overlies the Keban Metamorphites, Elazig Magmatites and Kirkgeçit Formation. It is unconformably overlain by Pleistocene aged alluvium (Palutoğlu, 2014).

3.2.6 Alluvium

These alluvial (Pleistocene; Qal1, Qal2, Qal3) sediments, which show a wide distribution in the study area, are classified in three different units due to their various lithologies. Silty clay (Qal_1), sandy gravelly clay (Qal_2) and sand-gravel (Qal_3). Silty clay surfaces in the south-east of Sürsürü District, Kültür District, Olgunlar District, Hicret District, Akpınar District, Sarayatik District, Nailbey District, University District and Çarşı District. As the grain size increases towards the north, it is understood that the transportation was from north to south (Palutoğlu, 2014).

Elazığ Provincial Settlement Area is situated within the Eastern Anatolian Fault (EAF) System and has been tectonically active since the early Mesozoic. The basis of this activity is the formation of the Tethys Ocean in the Late Triassic with the rifting that alocated the Anatolian Plate from the Arabian Plate. The growth of this ocean continued since the Late Triassic onwards, reaching its greats opening in the early Late Cretaceous, and from this time onwards it began to close with an inclined subduction to the north, under the Eurasian Plate. Besides the one between the Bitlis-Pütürge Massif and the Arabian Plate, there is also an oceanic branch between the Bitlis-Pütürge Massif and the Keban-Malatya Metamorphites. Both of them started to close in the early Late Cretaceous and the northern branch closed at the end of the Late Cretaceous (Palutoğlu, 2014).

3.3. Seismicity of the Region

Earthquakes are ground tremors due to deformations of the earth's shell caused by internal dynamic forces and are described as faults in geology. The magnitude of an earthquake is related to the quantity of energy liberated through rupture (faulting). The energy liberated by tearing typically reduces regularly as one moves away from the centre of rupture. However, sometimes unfavourable ground conditions arising from local geological features can disrupt this condition and despite being far away from the source, the destructive effect of the earthquake may be higher than expected. Therefore, while assessing earthquake capacity of a territory, the earthquake reason faults (active faults) and regional ground properties should be well known. The faults affecting the seismicity of the region at macro and micro scales should be considered as follows. (Palutoğlu,2014)

3.3.1. Eastern Anatolia Fault System (DAFS)

They are left-directed strike-slip intracontinental transform faults. DAFS starts from Karlıova triple junction with KAFS at its northern end. At its southern end in the Antakya region, it connects to the Dead Sea fault system. It is estimated that the DAFS acquired transform fault characteristics in the Late Pliocene and its total throw is 15-20 km. Recent GPS measurements indicate that the annual slip rate on the DAFS is 10±1 mm. Historical and instrumental period documents demonstrate that DAFS has caused many destructive earthquakes. Studies limit the beginning of the formation age of the DAF to the Uppermost Pliocene. In other words, the DAF has been active since the Quaternary. Among the segments of the DAF system, Palu-Hazar Lake segment has the potential to generate earthquakes that will directly affect Elazığ and its vicinity, Hazar Lake-Sincik segment Malatya and its vicinity, Çelikhan-Erkenek segment Adıyaman and its vicinity, and Gölbaşı-Türkoğlu segment Kahramanmaraş and its vicinity. Considering the linear extension and lateral continuity of these segments, these faults are capable of generating M>7.0 earthquakes. (Palutoğlu, 2014)

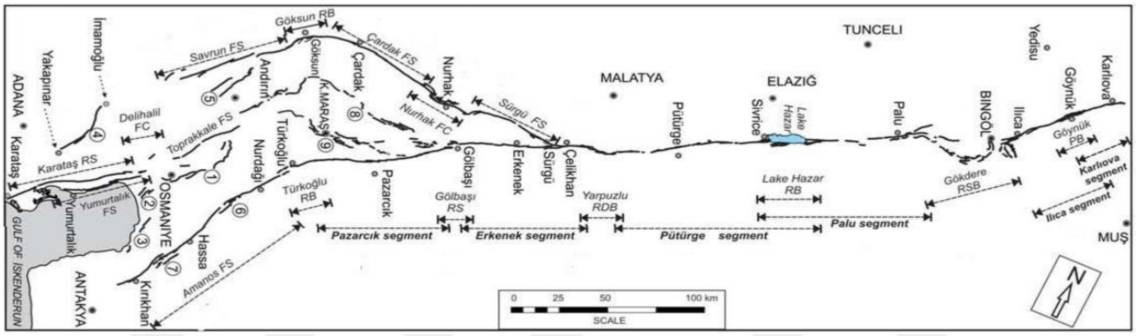


Figure 3.5. General geometry of the Eastern Anatolia Fault System (Duman and Emre, 2013)

The numbered segments of the Eastern Anatolian Fault Zone in the map shown in Figure 3.5 are; (1) Düziçi-Osmaniye fault segment; (2) Erzin fault segment; (3) Payas fault segment; (4) Yakapınar fault segment; (5) Çokak fault segment; (6) Islahiye free fold; (7) Demrek bounding thrust; (8) Engizek fault zone; (9) Maraş fault zone (Duman and Emre, 2013) .

The rocks surfacing in the immediate vicinity of the study area located on the Eastern Taurus Orogenic belt were affected by the tectonic movement of the Eastern Anatolian Fault Zone. This situation has led to the development of irregular fracture and fracture systems in the rocks surfacing in the region.

3.3.2. Elazig Fault

It was found appropriate to name this fault, which passes through the route of Abdullahpaşa Mahallesi - Cumhuriyet Mahallesi-Fırat University campus - İzzetpaşa Mahallesi - Ulukent Mahallesi - Doğukent Mahallesi in the settlement area of Elazığ city center, as the Elazığ fault.

Seismicity is generally determined as a function of tectonic activity in a region. It includes the parameters, frequency and epicentral intensity-distance correlations of earthquakes occurring in the region. In other words, it means determining all the characteristics of earthquakes occurring in the region. The purpose of determining the seismicity of a region is to assist in the preparation of earthquake resistant building projects. For this reason, the most important issue is to predict the largest earthquake force that will occur in the region within a certain time interval. Elazig Province is located in the dangerous earthquake zone with earthquake activity level DD-2nd degree.

According to the Turkish Building Earthquake Regulation of the Disaster and Emergency Management Presidency, which was published in the Official Gazette dated March 18, 2018 and numbered 30364 and entered into force on January 1, 2019, the earthquake motion level is DD-2.

The most important and closest fault that will affect the seismicity of the study territory is the Elazığ Fault, that passes through the north of the field territory. Elazig Fault extends in the northeast-southwest direction and constitutes the northern border of the plain called Ulu Ova. In the geotechnical and static studies to be carried out, it should be aimed to minimize the negative effects of earthquakes that may occur on this fault on the construction and necessary measures should be taken in this regard.

However, as we have seen from the Sivrice earthquake on 24.01.2020, the biggest earthquake for Elazığ is the DAFZ.

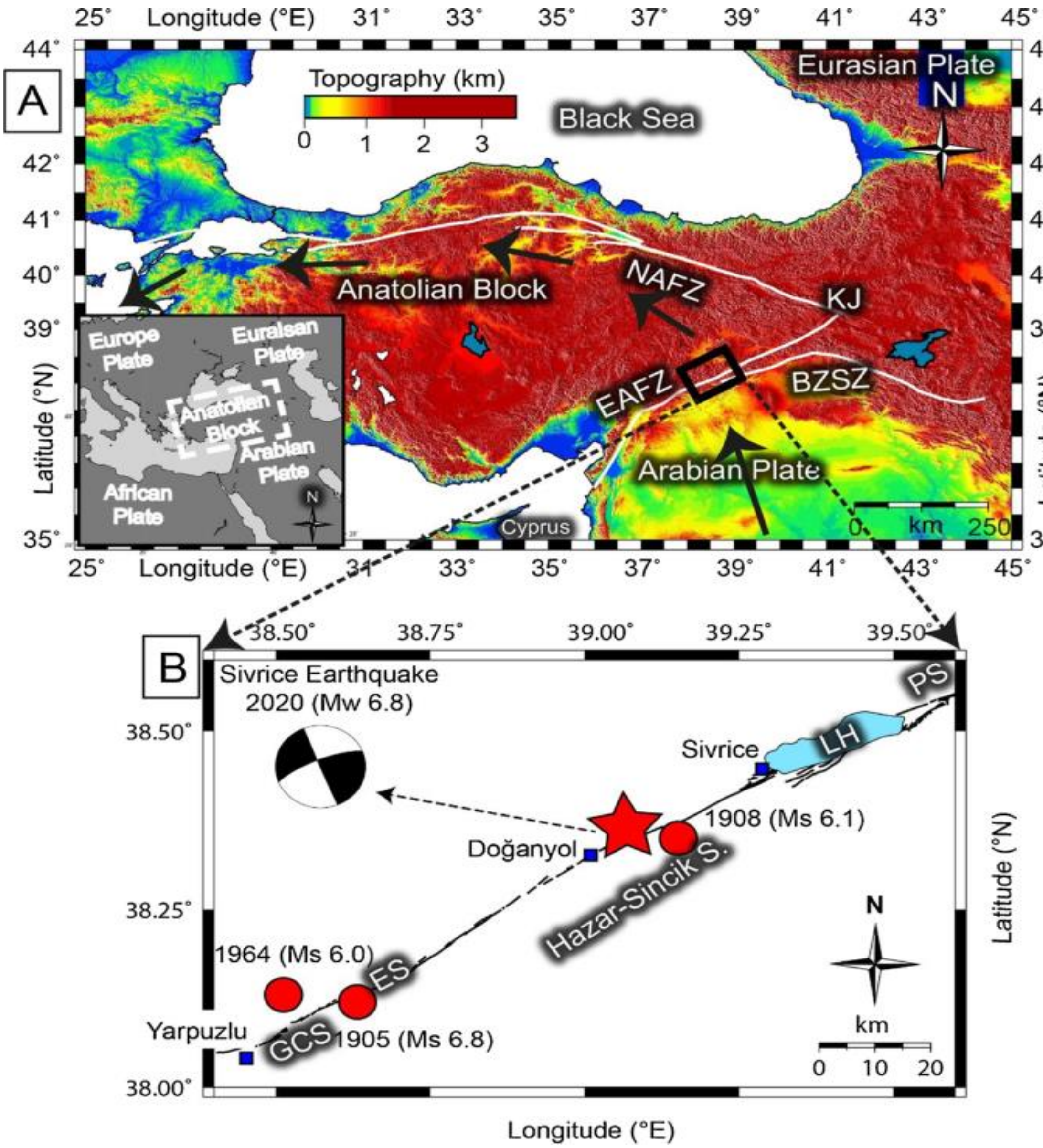


Figure 3.6. The 24 January 2020 (Mw 6.8) Sivrice (Elazig, Türkiye) earthquake: a first look at spatiotemporal distribution and triggering of aftershocks (Bayrak and Özer 2021)

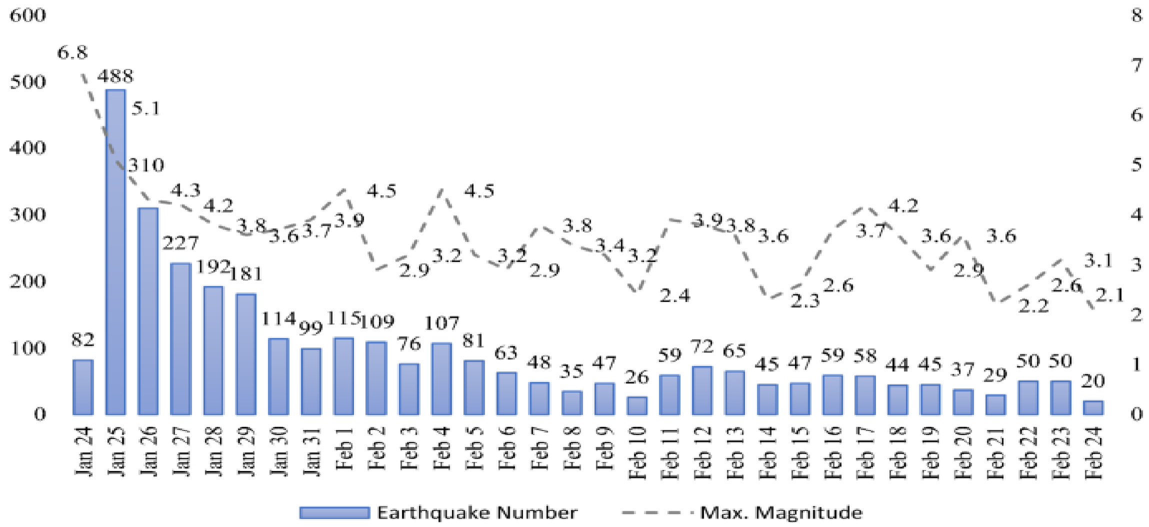


Figure 3.7. 24 January 2020 Sivrice-Elazığ, Türkiye earthquake: geotechnical evaluation and performance of structures (Sayın et al.2021)

Figure 3.7 shows that there were 2 earthquakes of magnitude 5.0≤Ms≤6.0, 28 earthquakes of magnitude 4.0≤Ms≤5.0, 184 earthquakes of magnitude 3.0≤Ms≤4.0, and 862 earthquakes of magnitude 2.0≤Ms≤3.0 in the period. There are 2053 earthquakes with magnitude 1.0≤Ms≤2.0. When this histogram is analysed, it is seen that the buildings to be constructed in this region should be constructed in accordance with the conditions specified in the "Regulation on Buildings to be Built in Earthquake Zones".

3.4. Climate Information of Elazig

Elazig has a continental climate. In addition to the continental climate, it has a Mediterranean climate in places. This climate change occurred after the Keban Dam was built. Elazig climate also shows a transition between Mediterranean and continental climate. Summers are hot and dry, winters are cold and harsh. The temperature ranges between -15°C and +42°C. The average annual precipitation is 433 mm. The most precipitation belongs to spring. Of the provincial territory, 25% is forest and heathland, 25% is cultivated and planted land and 42% is meadow and pasture. Land not suitable for cultivation is 8%. Forests are neglected. Valleys and around rivers are rich in vegetation (URL4).

3.5. Field Test

I prepared my master's thesis titled "Elazığ Sürsürü Neighborhood Microzonation" with the ground investigation reports made in Sürsürü Neighborhood, which I received from several different companies in Elazığ. In the reports we obtained, Standard Penetration Test, Pressiometer, MASW (Multi-channel Analysis of Surface Wave), DES (Vertical Electrical Drilling) field tests, water content, sieve analysis, Atterberg limits, relative volume weight, consolidation tests, laboratory tests and soil parameters were obtained.

3.5.1. Standard Penetration Test (SPT)

Standard Penetration Test (SPT) is essentially an in-situ dynamic shear test. Shear resistance depends on the relative firmness of the soil in granular soils and on the strength parameters of the soil in cohesive soils.

SPT test is the number of strokes obtained by dropping a 63.5 kg ram from a height of 76 cm in free fall and driving a 45 cm long SPT tube into the ground.

The spalled samples taken during the SPT tests were taken with a 2" outer diameter and 1 ⅜" inner diameter slit sampler. In all of the exploratory boreholes pierced in the field territory, standard penetration tests (SPT) were performed at depths of 0.00-20.00 meters in 1.5-meter increments of 1.5 meters each, with 12 standard penetration tests (SPT) in each well. SPT N30 recorded the lowest number of blows as 4 and the highest number of blows as 70. In some levels, the values were low due to loose clay in the levels taken in SPT samples.

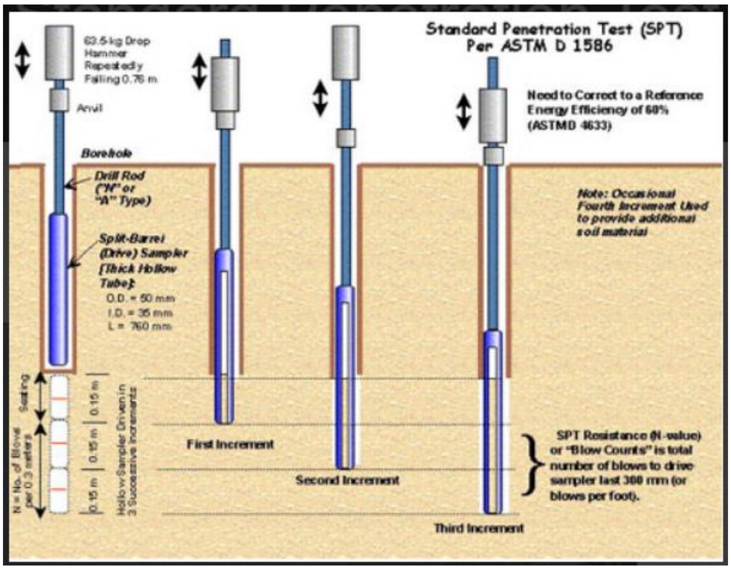


Figure 3.8. Construction stages of standard penetration test (Erol and Çekinmez, 2014)

Table 3.1. Soil classification according Turkish Standards (TS EN ISO 14688-2)

TS EN ISO 14688-2					
Criteria for determining symbols and names of soil groups based on laboratory tests				Ground Classification	
				Symbol	Group Name
COARSE-GRAINED SOILS (more than 50 % above 0.063 mm sieve)	GRAVEL	Clean Gravel (if fine grain content is less than 5 %)	$Cu \geq 15$ and $1 \leq Cc \leq 3$	GrW	Well Graded GRAVELS
			$6 \leq Cu < 15$ and $Cc < 1$	GrM	Medium Graded GRAVELS
			$3 \leq Cu < 6$ and $Cc < 1$	GrP	Poorly Graded GRAVELS
			$Cu < 3$ and $Cc < 1$	GrU	Uniformly Graded GRAVELS
			$Cu \geq 15$ and $Cc \leq 0{,}5$	GrG	Intermittently Graded GRAVELS
		Silty and Clayey Gravel (if fine grain content is more than 15 %)	If Silts and Clays are classified as SiL, SiM, SiH or SiV	siGr	Silty GRAVEL
			If Silts and Clays are classified as CiL, CiM, CiH or CiV	ciGr	Clayey GRAVEL
	SAND	Clean Sand (if fine grain content is less than 5%)	$Cu \geq 15$ and $1 \leq Cc \leq 3$	SaW	Well Graded SAND
			$6 \leq Cu < 15$ and $Cc < 1$	SaM	Medium Graded SAND
			$3 \leq Cu < 6$ and $Cc < 1$	SaP	Poorly Graded SAND
			$Cu < 3$ and $Cc < 1$	SaU	Uniformly Graded SAND
			$Cu \geq 15$ and $Cc \leq 0{,}5$	SaG	Intermittently Graded SAND
		Silty and Clayey Sand (if fine grain content is more than	If Silts and Clays are classified as SiL, SiM, SiH or SiV	siSa	Silty SAND
			If Silts and Clays are classified as CiL, CiM, CiH or CiV	ciSa	Clayey SAND
FINE GRAINED SOILS (50% or more passing through 0,063 mm sieve)	Liquid Limit less than 35%	Inorganic	$Ip \geq 7$ or over and above the A-line	CIL	Low Plasticity CLAY
			$Ip < 4$ or below the A-line	SiL	Low Plasticity SİLT
	Liquid Limit between 35% and 50%	Inorganic	On or above the A-line	CIM	Medium Plasticity CLAY
			Below the A-line	SiM	Medium Plasticity SILT
	Liquid Limit between 50% and 70%	Inorganic	On or above the A-line	CIH	High Plasticity CLAY
			Below the A-line	SiH	High Plasticity SILT
	Liquid Limit more than 70%	Inorganic	On or above the A-line	CIV	Very High Plasticity CLAY
			Below the A-line	SiV	Very High Plasticity SILT
ORGANIC GROUND	Primarily Organic Matter, Dark Colour and Organic Odour			Or	Organic Ground

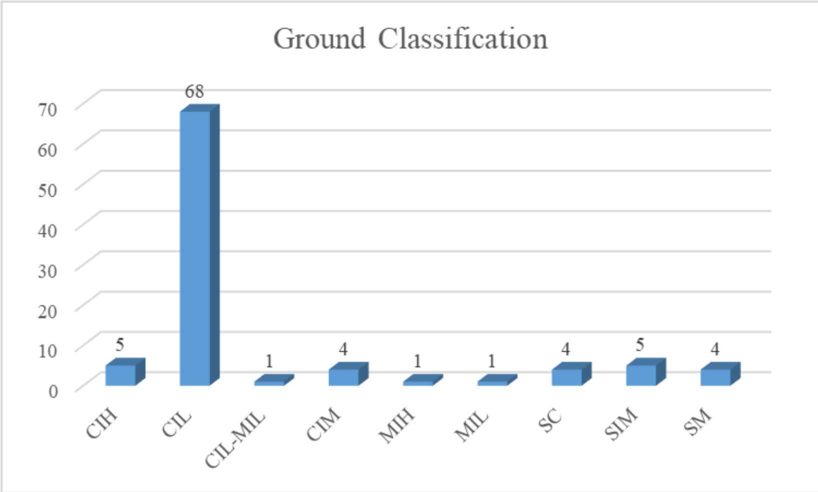


Figure 3.9. Classification of samples taken from boreholes according to TS EN ISO 14688-2 for the field and laboratory tests

3.5.2. Pressuremeter

In soil investigation studies, the pressuremeter test is an in-situ test in which the load/deformation characteristics of the ground are determined. In simple terms, the test is performed by lowering an expandable cylindrical probe into a pre-drilled well and inflating it, while measuring the pressure and volume changes in the probe. It is a method used in order to determine the bearing capacity of the soil, the settlement and different settlement amounts that will occur under the foundation, especially in gravelly, sandy, clayey, silty, alluvial soils and degraded, weathered rocks and soft rock foundations.

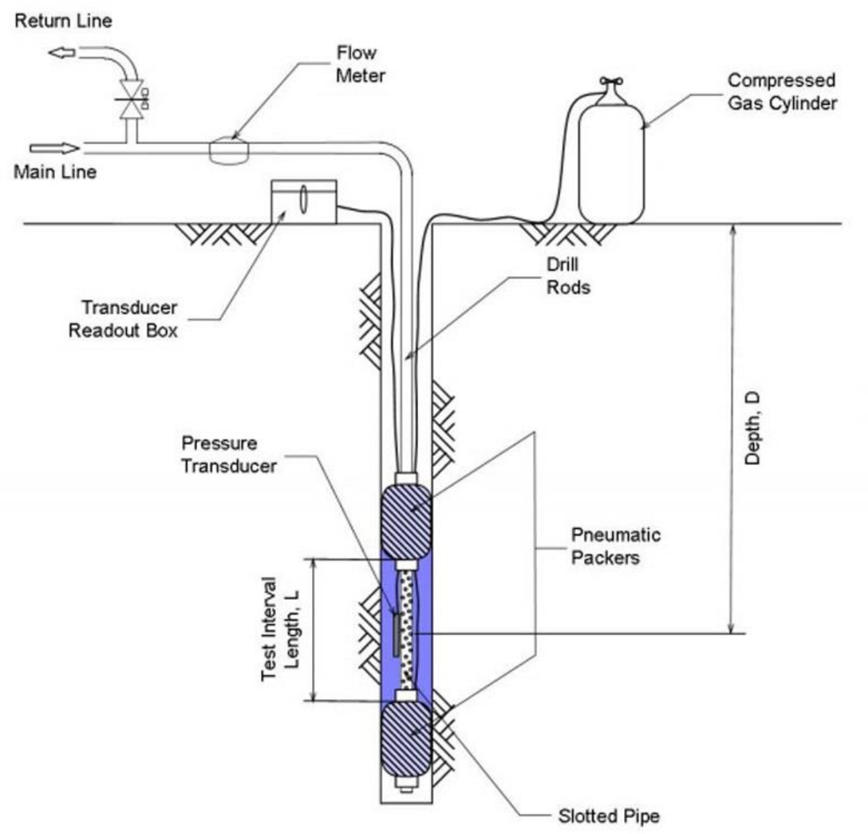


Figure 3.10. Application of pressuremeter test in the field (Ali et al., 2012)

3.5.3. MASW (Multi-channel Analysis of Surface Wave)

Since engineering studies are carried out in urban and confined areas, it has not always been possible to obtain the required length of seismic refraction for the targeted survey depth. In built-up areas, the signal-to-noise ratio is usually low and it is difficult to place receivers with long streaks. Also, in built-up areas, a sufficiently large energy source may not be available and the survey depth will be limited. In cases where the alluvium thickness is thicker than 30 meters, it is very difficult to detect the seismic foundation by seismic refraction. For these reasons, it is advantageous to use surface waves traveling with long wavelengths at low frequencies in residential areas, and the data collection and processing stages are faster and easier (Park et al. ,2005).

In surface wave methods, S-wave velocity modeling is performed from the inverse solution of dispersion information from data recorded by receiver arrays placed in a specific geometry. In this study, the Rayleigh wave dispersion curve is obtained using the active source method, the Multichannel Surface Wave Method (MASW). Shear wave velocities are estimated from the inverse solution of the dispersion curves.

By analyzing the basic mode of Rayleigh surface waves, the S wave velocity structure that varies with depth can be extracted. With the S-wave velocity structure obtained from the inverse solution of the dispersion data of the surface waves, The dynamic features of the ground and the profundity of the bedrock and the thickness of the overlying layers can be determined.

Figure 3.11. Application of MASW test in the field (photo)

A sledgehammer weighing 8 kg was utilised as a seismic source. After the measurements, the data were modeled in 1D using the 1-D PickWin / Surface Wave Analysis software in Doremi's Seismiager software.

3.5.4. Dynamic and Static Parameters Obtained from Geophysical Methods

In order to determine the P and S wave velocities, reciprocal shots were made in 1 profile and the time-distance (x-t) graphs of the shots were drawn, the layer velocities were calculated from the lines drawn and the elastic parameters of the soil were found from these velocities.

When we look at the Masw measurements taken on alluvium (Qal) units throughout the study area, Vs velocities are low in the first layers but high values are calculated in the lower layers. This is due to the fact that the units in the study area are more compact towards the depths. The mean shear wave velocity values for the depth of the foundation in the study area are approximately (V_S m/sec) with at least 175 and up to 438 m/sec in the field area.

Salem (2000) stated that although it is not possible to generalise these results obtained in a certain region in alluvial soils, it can be considered that the regions where the V_p/V_s ratio, which is defined as the seismic velocity ratio of the given results, is greater than 3 may indicate water saturated soils, while Keçeli (2010) defines it as a medium densely degraded soil for a value of 3. It is also stated by Başokur (et al. 2002) that V_P/V_S cross sections can provide qualitative information about the water content of soils in this respect. In our data, the lowest V_P/V_S ratio was determined as 1.40 and the highest V_P/V_S ratio was determined as 3.47.

3.5.4.1.Seismic P-wave (Longitudinal Wave Velocity (Vp))

Such waves are called compression or first waves. During the propagation of these waves there is cubic expansion or volume change due to compression. In longitudinal waves, the vibration direction representing compression and expansion is the same as the wave propagation direction. Therefore, the P-wave velocity will be low in compressible (loose) soils and high in difficult-to-compress soils (rock).

$$Vp = \sqrt{\frac{\lambda+2\mu}{\rho}} = \sqrt{\frac{E(1-\sigma)}{\rho(1+\sigma).(2-\sigma)}} \tag{3.1}$$

V_P = P Wave Velocity (m/sec)

λ = Wave Length

μ = Bulk Modulus (kg/cm^2 - N/m^2)

ρ = Density (kg/m^3)

E = Young Modulus (N/m^2)

Table 3.2. Excavability of soils with P-wave velocity (Church, 1981)

P Wave Velocity (m/sec)	Engravability
≤458	Very Easy Engravable
458-1220	Easy Engravable
1220-1525	Medium-Hard Engravable
1525-1830	Hard Engravable
1830-2135	Very Hard Engravable
>2135	Explosive Engravable

The classification of scrapeability according to P-wave velocity in the paving was found as 1st layer velocity was the lowest 226 m/sec (easily excavable), 2nd and 3rd layer velocities were the highest 1920 m/sec (very difficult to engravable).

3.5.4.2. Seismic S-Wave (Shear Wave (Vs))

Deformation, i.e. angle changes, are observed in the elements while shear waves spread. This is because the direction of vibration of the particles in wave propagation is vertical to the direction of wave diffusion. Shear wave velocities inherently occur when the object is strength to deformation or torsion. The reason why the S-wave velocity is "0" in water is that water has no resistance to torsion and deformation and can be cut.

$$Vs = \sqrt{\frac{\mu}{\rho}} = \sqrt{\frac{E}{2\rho(1+\sigma)}} \qquad \textbf{3.2}$$

μ= Bulk Modulus (kg/cm^2 - N/m^2)

ρ = Density (kg/m^3)

E = Young Modulus(N/m^2)

σ = Poisson Ratio

Table 3.3. Soil Classification According to NEHRP Provisions

Ground Class	Definition	Features
A	Hard Rock	Vs>1500
B	Rock	760<Vs<=1500
C	Very Stiff / Hard Soil or Soft Rock	360<Vs<=760
D	Hard/Dense Soil	180<Vs<=360
E	Weak Soil	Vs<180

The shear wave velocity values obtained as a result of the seismic study in the study area are classified in the NEHRP international soil classification chart as "D Hard/Dense Soil" with the lowest value of 301 m/sec and "C, Very Stiff/Hard Soil-Soft Rock" with the highest value of 419 m/sec for the V_{S30} value, which is the average value for 30 m depth. The study area is generally calculated as "D Hard/Dense Soil" and rarely classified as "C, Very Stiff/Hard Soil-Soft Rock".

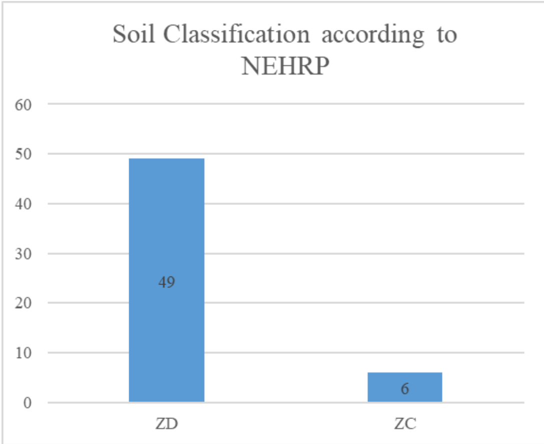


Figure 3.12. Soil classification according to NEHRP

3.5.4.3. Modulus of Elasticity (E_d, kg/cm^2)

The modulus of elasticity is defined as the ratio of stresses (strains) to strains (deformations) in one direction. In other words, it is the vertical deflection of the earth in the direction of the applied vertical pressure.

$$E=2\mu(1+\sigma)\ kg/cm^2 \quad 3.3$$

Table 3.4. Strength of soils or rocks according to modulus of elasticity values (Keçeli, 1990)

Modulus of Elasticity – E- kg/cm^2	Feature
<1000	Very Weak
1000-5000	Weak
5000-10000	Medium
10000-30000	Strong
>30000	Very Strong

If we solve the Modulus of Elasticity for each layer according to the above model

$$E=G*(3*V_p^2-4*V_s^2)/(V_p^2-V_s^2) \quad 3.4$$

The modulus of elasticity values obtained as as a consequence of the work conducted in the field territory are classified as "Very Weak" according to the Keçeli 1990 classification since the lowest 552 and the highest 6572 kg/cm^2 values for the 1st layer according to the Keçeli 1990 classification, and as the lowest 4723 and the highest 10912 kg/cm^2 values for the 2nd layer according to the Keçeli 1990 classification, the resistance to vertical shearing is classified as "Medium" (arithmetic mean of the values) according to the Keçeli 1990 classification.

3.5.4.4.Shear Modulus (G_{max}, kg/cm^2)

Shear Modulus shows the resistance of the formation against shear stresses, i.e. horizontal forces. Since liquids have no resistance to shear, this coefficient is zero The greater the shear modulus, the higher the strength of the formation against shear stresses, i.e. horizontal forces (horizontal earthquake load).

Shear Modulus is calculated in 2 ways.

1) $\mu = \rho * V_s^2$ **3.5**

is calculated from the formula. Here

$\rho = \gamma_n / g$ **3.6**

is calculated from the formula. ρ=density, γ_n=natural (total) unit volume weight, g=gravity acceleration (9.8 m/sec^2).

2) Specific Gravity $d = 0.31 * V_p^{0.25}$ **3.7**

where $\mu = (d * V_s^2)/100$ (kg/cm^2) **3.8**

According to the above model, the Shear Modulus is calculated as follows.

Table 3.5. Strength of soils or rocks according to shear modulus values (Keçeli, 1990)

Shear Modulus (Gmax, kg/cm^2)	Feature
<400	Very Weak
400-1500	Weak
1500-3000	Medium
3000-10000	Strong
>10000	Very Strong

The shear modulus values obtained as a result of the studies carried out in the study area were measured as 368 kg/cm^2 at the lowest value and 7663 kg/cm^2 at the highest value.

3.5.4.5. Bulk Modulus (μ, kg/cm^2)

Bulk Modulus is the measure of compression under pressure surrounding an enclosure. Bulk modulus obtained from wave theory;

$$\mu = (E/3(1-2\sigma)) \text{ kg/cm}^2 \quad 3.9$$

$$\mu = ((d(V_p^2 - 4/3V_s^2)/100) \text{ kg/cm}^2 \quad 3.10$$

Table 3.6. Strength of soils or rocks according to bulk modulus values (Keçeli, 1990)

Bulk Modulus (μ, kg/cm^2)	Compression
<400	Very Low
400-10000	Low
10000-40000	Medium
40000-100000	High
>1000000	Very High

Bulk modulus values obtained as a result of the studies carried out in the investigation area were generally measured as the lowest 680 kg/cm^2 and the highest 71710 kg/cm^2 in both layers.

3.5.4.6. Density: (ρ , gr/cm^3)

According to the longitudinal wave velocity, the density given empirically by Telford et al. (1976) is calculated from the following formula.

$$\rho = d = 0.31 * V_p^{0.25} \text{ (gr/cm}^3) \quad 3.11$$

Table 3.7. Descritions of Soil Density Classification (Keçeli, 1990)

Density(ρ, g/cm^3)	Description
<1.20	Very Low
1.20-1.40	Low
1.40-1.90	Medium
1.90-2.20	High
>2.20	Very High

As a result of the studies carried out in the study area, the density values of the units in the field were calculated as the lowest 1.4 kg/cm^3 and the highest 2.0 kg/cm^3 within the general strata.

3.6. Soil Amplification

Earthquake waves pass through soil layers to reach the structure. As the earthquake waves pass through the ground layers, they undergo changes depending on the local characteristics of the ground and the earthquake waves are amplified or damped by this change. This increase in the amplitude of earthquake waves travelling through soil layers is defined as ground amplification in the literature. The amplified motion transmitted to the foundation of the structure increases the deformation levels on the structural elements and results in possible local collapse or structural collapse. Very small values of bedrock accelerations can be amplified several times in some regions with the effect of local conditions and can cause very severe damage (Kramer, 1996). While dynamic earthquake loads cause problems such as amplification and liquefaction in the ground, static loads cause problems such as bearing capacity, ground safety stress, settlement and consolidation in the ground. The results of the researches carried out after major earthquakes have shown that the differences in local soil conditions cause differences in structural damages. The soil amplification is influenced by the empadance ratio of the material, sub-basin topography, basin edge effect, ground surface topography and soil structure-texture.

3.6.1. Impedance Ratio

Impedance ratio (α), which is expressed as the ratio of velocity and density products at the bedrock / soft ground layer transition (Yalçınkaya, 2010), is defined more broadly as the product of rock density and S-wave velocity in the rock divided by the product of the density of the ground layer and the S-wave velocity in this layer; the larger the impedance ratio, the larger the seismic wave amplitude. This concept is considered as the resistance of the medium against particle motion (Aki and Richards, 1980). The magnitude of the wave amplitude at the ground is directly proportional to the height of the impedance and inversely proportional to the damping ratio (Roesset, 1977).

3.6.2. Damping

Damping is the reduction of wave energy over a period of time, again due to various factors. Gazetas et al. (1990) state that during earthquakes, the intensity of ground motion and the resulting damage depend on local ground conditions due to the properties of the soil layers at these locations. Local ground conditions not only increase the amplitude, but sometimes cause a decrease in amplitude, known as damping.

3.6.3. Site Dominant Vibration Period

The frequency of the seismic wave does not consist of a single frequency since it is affected by the characteristics of the rupture at the centre of the source and the characteristics of the environments through which the propagating wave passes. The frequencies of damaging earthquake waves generally vary between 0.1 Hz and 10 Hz. Due to the different properties of the ground, the effects on the properties of seismic waves vary, because some frequencies are amplified more and some frequencies are amplified less. The amplification of the ground layer depends on the impedance ratio and damping ratio, while the frequency at which this amplification occurs depends on the S-wave velocity and thickness of the ground. The period (or frequency) of maximum amplification, T_0, is often referred to as the ground dominant period (or ground dominant frequency). In case of damping, damping is more effective at high frequencies, which causes a significant decrease in the amplification effect after the first frequency (Yalçınkaya, 2010). The first period or frequency at which the maximum amplification is observed is known as the resonance period or frequency, and the frequencies of two different vibrations interacting at resonance coincide and the amplitude is maximised. The main purpose of preventing resonance in earthquakes is that the dominant period of the ground and the dominant period of the structure, which depends on the size of the structure and the material properties of the structure, do not coincide. When the event is evaluated in terms of energy, the fact that the structure will be exposed to a greater destruction energy as the square of the amplification reveals the importance of ground amplification in research.

Site dominant vibration period (Kanai, 1983),

$$T_0 = \Sigma\ 4Hi / Vsi \qquad 3.12$$

T_0; frequency and period at which maximum amplification will be seen,
H; thickness of the soil layer over the hard bedrock,
V_S; is the shear wave velocity of the soil layer.

Table 3.8. (a) Microzonation criteria according to site dominant vibration periods (b) Microzonation criteria according to spectral amplifications (Ansal et al. , 2004)

(a)		**(b)**	
Site Dominant Vibration Period Range	**Criteria Definition**	**Spectral Amplification**	**Hazard Level**
0.10 – 0.30 sec	A	0.0 – 2.5	A (Low)
0.30 – 0.50 sec	B	2.5 – 4.0	B (Medium)
0.50 – 0.70 sec	C	4.0 – 6.5	C (High)
0.70 – 1.00 sec	D		

The site dominant vibration period value calculated with the help of Shear Wave Velocities and layer thicknesses obtained in the study area was measured as 0.47 sec minimum and 0.66 sec maximum. These values are classified as "C, High hazard level" according to the classification made by Ansal et al. 2004.

3.7. Impact Coefficients for Local Soil Classification

SS : Short period map spectral acceleration coefficient (dimensionless)

S1 : Map spectral acceleration coefficient for 1.0 second period (dimensionless)

SDS : Short period design spectral acceleration coefficient (dimensionless)

SD1 : Design spectral acceleration coefficient for 1.0 second period (dimensionless)

PGA : Maximum ground acceleration (g)

PGV : Maximum ground velocity (cm/sec)

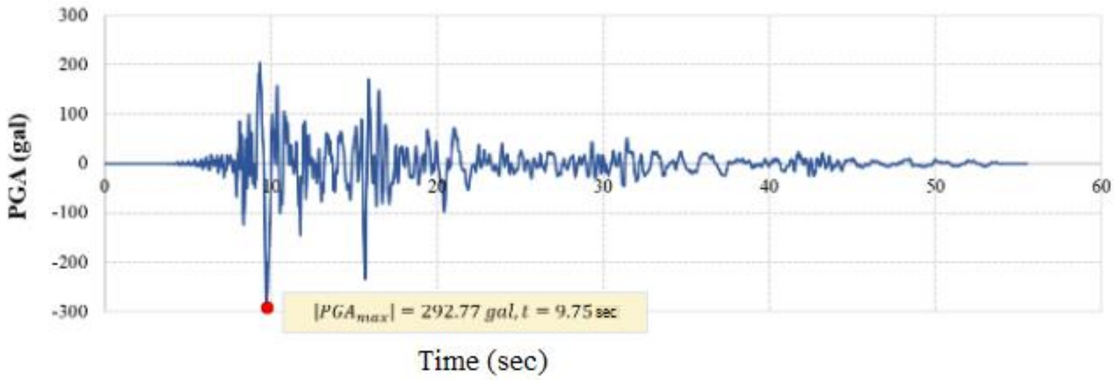


Figure 3.13. Acceleration-time graph in east-west direction obtained from Sivrice station

Table 3.9. Earthquake parameters for different levels of earthquake ground motion

2308 Sivrice Station				
PGA (for DD-2 earthquake ground motion level):0.662 g				
	DD1	DD2	DD3	DD4
S_s	2.762	1.504	0.539	0.330
S_1	0.778	0.396	0.126	0.075
S_{DS}	3.314	1.805	0.692	0.429
S_{D1}	1.089	0.594	0.189	0.113
PGA	1.101	0.622	0.230	0.145
PGV	82.291	44.035	12.853	7.463

Table 3.10. Local soil impact coefficients for 1.0 second period (TBDY, 2018)

Local Ground Class	For 1.0 second period *Local Soil Impact Coefficient F_1*					
	$S_1 \leq 0.10$	$S_1 = 0.20$	$S_1 = 0.30$	$S_1 = 0.40$	$S_1 = 0.50$	$S_1 \geq 0.60$
ZA	0.8	0.8	0.8	0.8	0.8	0.8
ZB	0.8	0.8	0.8	0.8	0.8	0.8
ZC	1.5	1.5	1.5	1.5	1.5	1.4
ZD	2.4	2.2	2.0	1.9	1.8	1.7
ZE	4.2	3.3	2.8	2.4	2.2	2.0
ZF	*Site specific soil behaviour analysis will be performed*					

Table 3.11. Local soil impact coefficients for short period (TBDY, 2018)

Local Ground Class	For short period region *Local Soil Impact Coefficient F_s*					
	$S_S \leq 0.25$	$S_S = 0.50$	$S_S = 0.75$	$S_S = 1.00$	$S_S = 1.25$	$S_S \geq 1.50$
ZA	0.8	0.8	0.8	0.8	0.8	0.8
ZB	0.9	0.9	0.9	0.9	0.9	0.9
ZC	1.3	1.3	1.2	1.2	1.2	1.2
ZD	1.6	1.4	1.2	1.1	1.0	1.0
ZE	2.4	1.7	1.3	1.1	0.9	0.8
ZF	*Site specific soil behaviour analysis will be performed*					

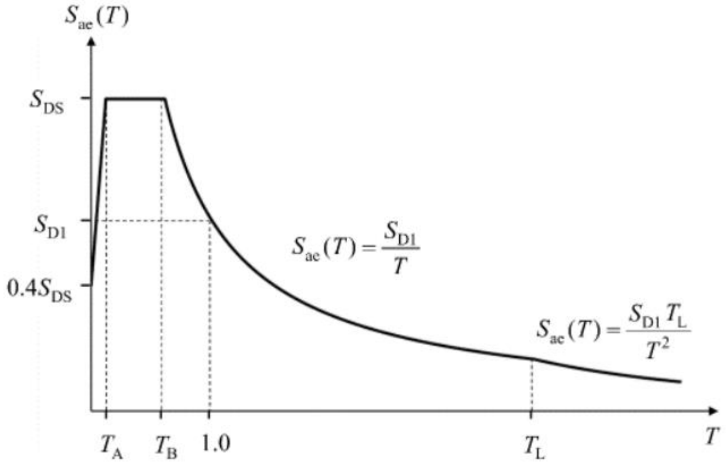


Figure 3.14 Design acceleration spectrum (TDBY, 2018)

Table 3.12. Detailled **t**able of local soil classes according to Türkiye Building Earthquake Regulations (TBDY, 2018-Table 16.1)

Local Soil Class	**Soil Type**	**Average in the upper 30 metres**		
		$(V_s)_{30}$ (m/sec)	**$(N_{60})_{30}$ (blow/30 m)**	**$(c_u)_{30}$ (kPa)**
ZA	Solid, hard rocks	>1500	-	-
ZB	Slightly weathered, moderately intact rocks	760-1500	-	-
ZC	Very compact layers of sand, gravel and hard clay or weathered, weak rocks with many cracks	360-760	>50	>250
ZD	Medium firm to firm sand, gravel or very stiff clay layers	180-360	15-50	70-250
ZE	Loose sand, gravel or soft to firm clay layers or Profiles containing a soft clay layer (c_u <25 kPA) thicker than 3 metres in total, meeting the conditions PI>20 and w>40%	<180	<15	<15
ZF	Soils that do not require site-specific investigation and evaluation: 1)Soils with the risk of collapse and potential collapse under earthquake effect (liquefiable soils, highly sensitive clays, collapsible weak cement soils, etc.). 2) Peat and/or clays with high organic content with a total thickness of more than 3 metres, 3)High plasticity (PI>50) clays with a total thickness of more than 8 metres, 4)Very thick (>35 m) soft or medium stiff clays.			

In the Turkish Building Earthquake Code (2018), which has been in current use since 2019, the subject of soil behaviour analyses has been included as a result of increasing knowledge and developing technological applications in geotechnical earthquake engineering studies. In TBDY (2018), soils are presented in 6 classes and the parameters $(V_S)_{30}$ (average shear wave velocity (m/sec) in the upper 30 metres), $(N_{60})_{30}$ (average standard penetration impact number in the upper 30 metres) and $(c_u)_{30}$ (average undrained shear strength (kPa) in the upper 30 metres) were used to determine the classes.

3.8. Deepsoil v.7 Software

Nowadays, one-dimensional soil behaviour analyses are based on two basic principles, namely uniform linear and nonlinear behaviour calculations. Uniform linear soil behaviour calculations are frequency domain analyses and are more widely used in soil behaviour analysis studies because they require less mathematical computation (Kramer and Arduino, 2009; Phillips and Hashash, 2009). However, equivalent linear analyses have some limitations. Due to these limitations, the analysis cannot fully reveal the nonlinear attitude of the ground. The equivalent linear approach is based on the assumption that there is a coequal shear modulus and damping for every ground layer. It is argued that various shear moduli and different damping ratios when installing cyclically can occur for all soil layers during the entire duration of the seismic motion (Phillips and Hashash, 2009). Hashash et al. (2010) and Bolisetti et al. (2014) state that the behaviour of grounds under installing cyclically, especially in soils consisting of soft soil layers (soft alluvial deposits) of seismic movement is dense, is generally nonlinear and is affected by various factors like loading magnitude, number of cycles, soil properties as well as ambient stress. Therefore, they propose nonlinear soil behaviour for areas in which weak soils are widely distributed or strong seismic motions occur. The present research uses the one-dimensional uniform linear and nonlinear soil behaviour analysis methods recommended in TBDY 2018 to identify the ground properties and their behaviour under earthquake effects in the Sursürü District in the central district of Elazığ, in alluvial deposits with a depth of approximately 500 m, although medium plasticity is observed in alluvial deposits and mainly consisting of low plasticity soils. The analyses were performed with Deep Soil 7 software.

The Deepsoil software was developed by Youssef MA Hashash, Professor of Civil and Environmental Engineering, Guangchao Xing, Graduate Research Assistant, Karim AlKhatib, Graduate Research Assistant, and Karim AlKhatib, Graduate Research Assistant, from the University of Illinois at Urbana-Champaign. Deepsoil, which was first developed in 1998 based on the working principle of one-dimensional soil behaviour analyses, can perform both uniform linear and nonlinear analyses with both frequency and time domain analyses (Groholski et al., 2016).

DEEPSOIL is a unified 1D equivalent linear and nonlinear site response analysis platform. The main general features are

- Strength-controlled nonlinear model
- Frequency-independent damping formulation
- Porewater pressure generation and dissipation models
- Graphical user interface
- Parallel-processing capability

3.8.1. Nonlinear Site-Specific Soil Behaviour Analysis With Deepsoil Software

Earthquake records to be used in non-linear soil behaviour analysis should be defined to Deepsoil program, which is used in site-specific behaviour analyses because it provides realistic results in soil modelling. The program, which offers solutions in frequency and time domain, provides users with the opportunity to choose the analysis in the local soils model to be modelled. DeepSoil program can also be used for equivalent linear analysis and nonlinear site specific behaviour analysis. In this thesis, the soil profile was modelled in the DeepSoil program because it allows the earthquake performance of the site to be reflected realistically by modelling the presence of layers in a realistic way, observing the effects of pore water pressure and seeing how earthquake waves affect the behaviour of the soil itself.

An ideal ground was created with the results of 72 drilling reports collected from various companies for use in the Depsooil programme. Sürsürü District has low plasticity in general. The lowest and highest calculated values of these boreholes are as follows, the lowest ground water level was measured as 3 m and the highest as 16 m. SPT N30 recorded the lowest number of blows as 4 and the highest number of blows as 70. The average shear wave velocity values for the depth of the foundation in the study area are approximately (V_{S1} m/sec) with a minimum of 175 and a maximum of 438 m/sec in the study area. The classification of scrapeability according to P-wave velocity in the paving was found as 1st layer velocity was the lowest 226 m/sec (easily excavable), 2nd and 3rd layer velocities were the highest 1920 m/sec (very difficult to engravable). NEHRP international soil classification chart as "D Hard/Dense Soil" with the lowest value of 301 m/sec and "C, Very Stiff/Hard Soil-Soft Rock" with the highest value of 419 m/sec for the V_{S30} value, which is the average value for 30 m depth. The study area is generally calculated as "D Hard/Dense Soil" and rarely classified as "C, Very Stiff/Hard Soil-Soft Rock". Bulk modulus values obtained as a result of the studies carried out in the investigation area were generally measured as the lowest 680 kg/cm^2 and the highest 71710 kg/cm^2 in both layers. The site dominant vibration period value calculated with the help of Shear Wave Velocities and layer thicknesses obtained in the study area was measured as 0.47 sec minimum and 0.66 sec maximum. The lowest ground amplification factor was 1.8 and the highest was 2.3. Effective Ground Acceleration Coefficient A_0 was measured as 0.381 at the lowest and 0.400 at the highest.

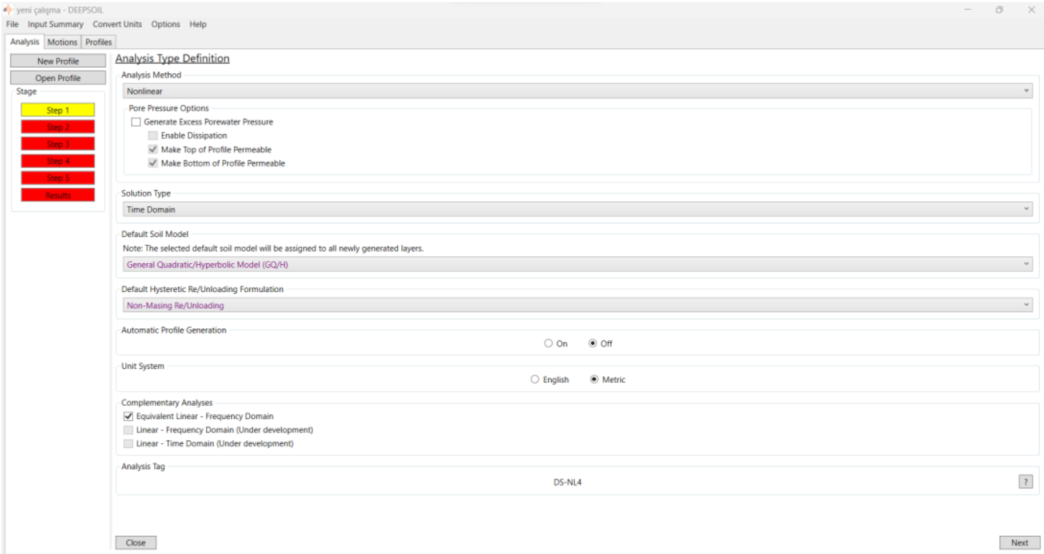


Figure 3.15. Login Screen of DeepSoil Software

While determining the DeepSoil analysis type, the equivalent linear and nonlinear analysis behaviour can be selected from the program home page in accordance with the soil conditions and for which behaviour analysis will be performed (Figure 3.15). The selection tab in the time or frequency definition field can be changed according to the analysis preference.

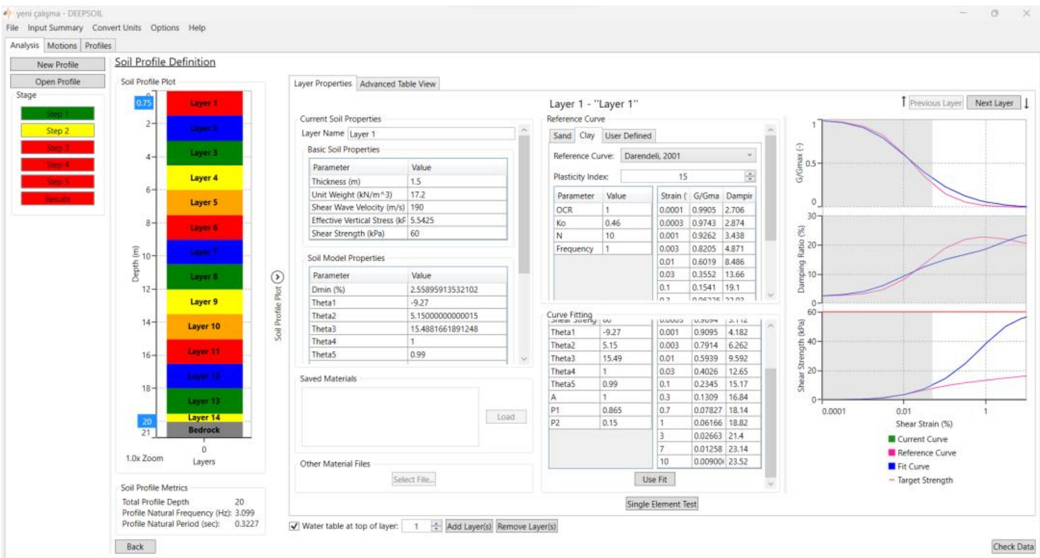


Figure 3.16. Data entry screen to be selected according to the properties of the layers

According to the soil profile determined in the Deepsoil programme, the layers and the parameters of the layers are processed and the soil profile is created in accordance with the cross section. In the software screens shown in Figure 3.15 it is possible to transfer the data to the programme depending on the layer properties, thus creating a stratified soil profile. Figure 3.16 shows the image of the soil profile consisting of 14 layers and the values imported into the programme.

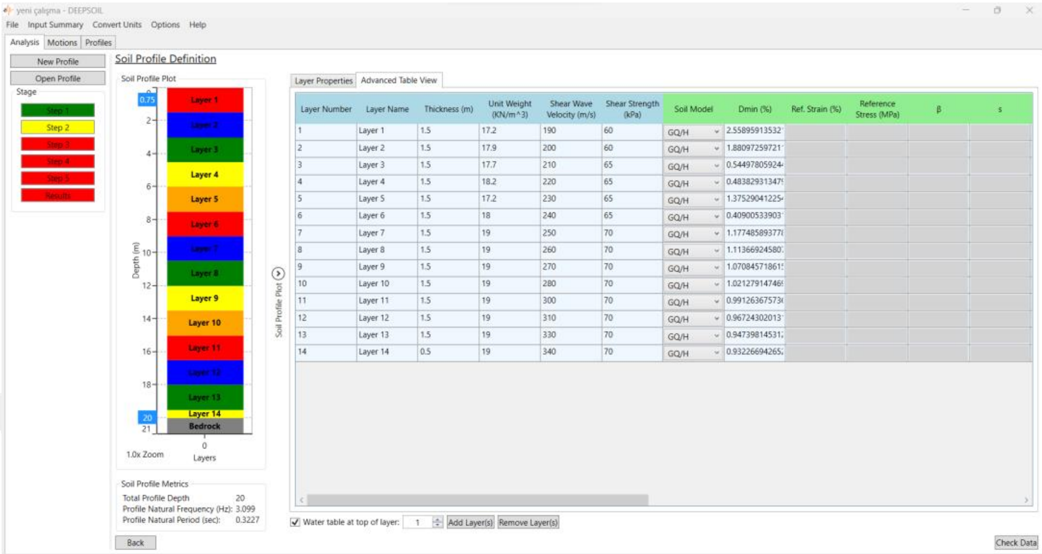


Figure 3.17. Layers formed with the help of parameters suitable for the soil profile

In this study, the second order hyperbolic soil model, which provides a good fit with the target damping curves in the time domain nonlinear analysis method, was used; while the curves of Darendeli (2001), which are used in many studies in the literature, were used for the selection of the attenuation and damping curves for clay-silt layers. For the determination of the Ko (horizontal pressure coefficient) parameter, the Iogampiric relation proposed by Alpan (1967) for clays in normal cosolids, based on PI and OCR values, was used. (Equation ZZ)

$$\mathbf{Ko=0.19+0.233\ logPI} \qquad \mathbf{3.13}$$

The shear strength of each 1.5 metre layer was calculated in accordance with the soil type.

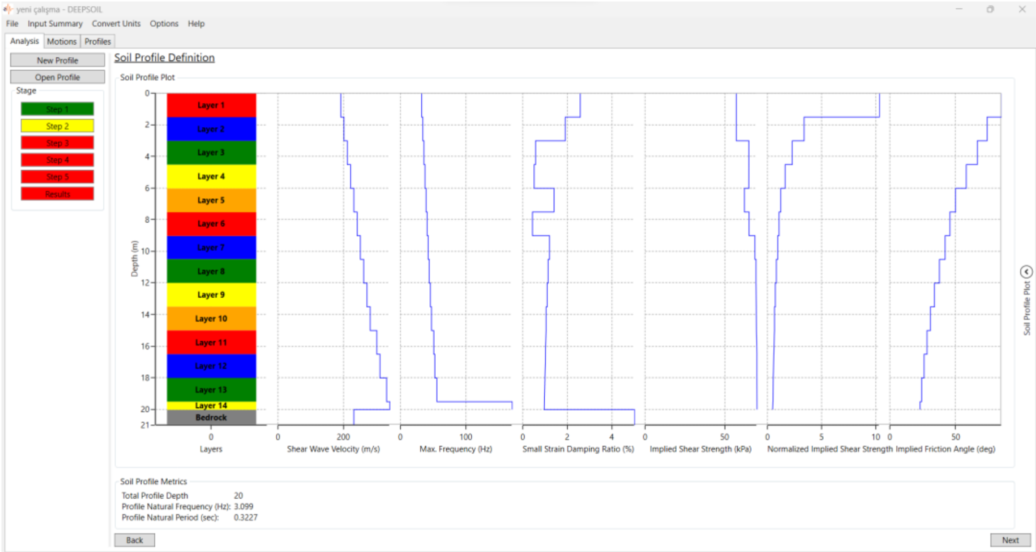


Figure 3.18. View of the layered soil model used in the study

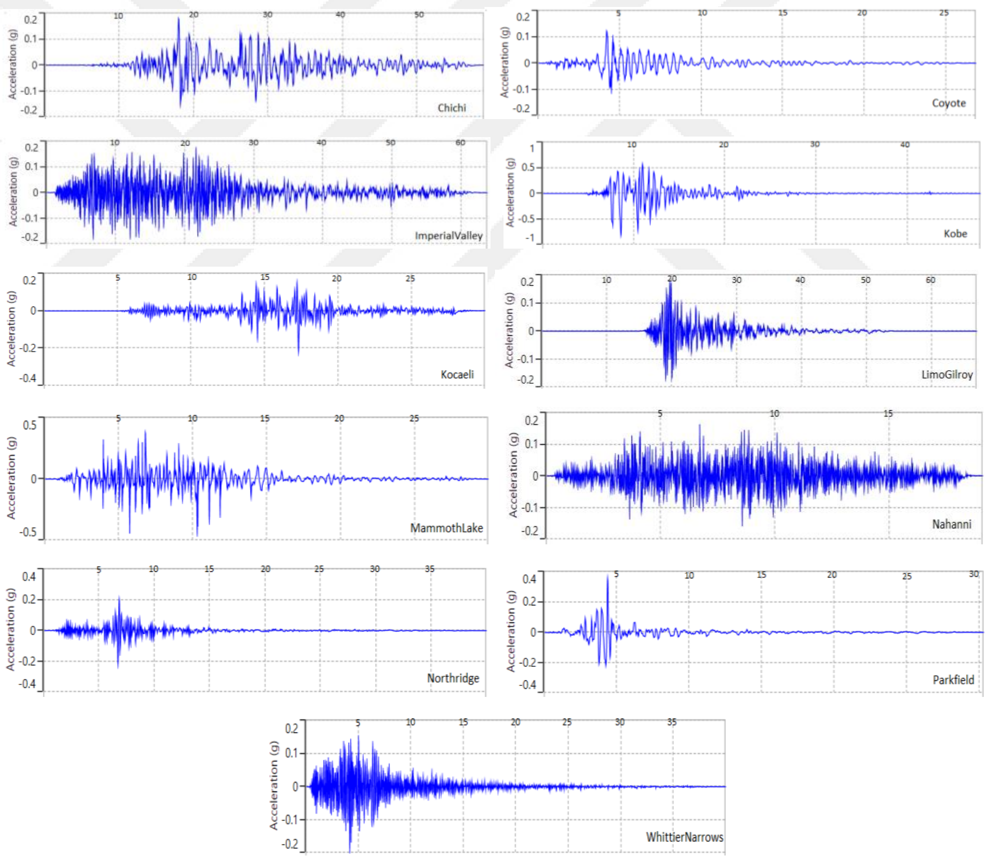


Figure 3.19. Acceleration records of the selected earthquakes

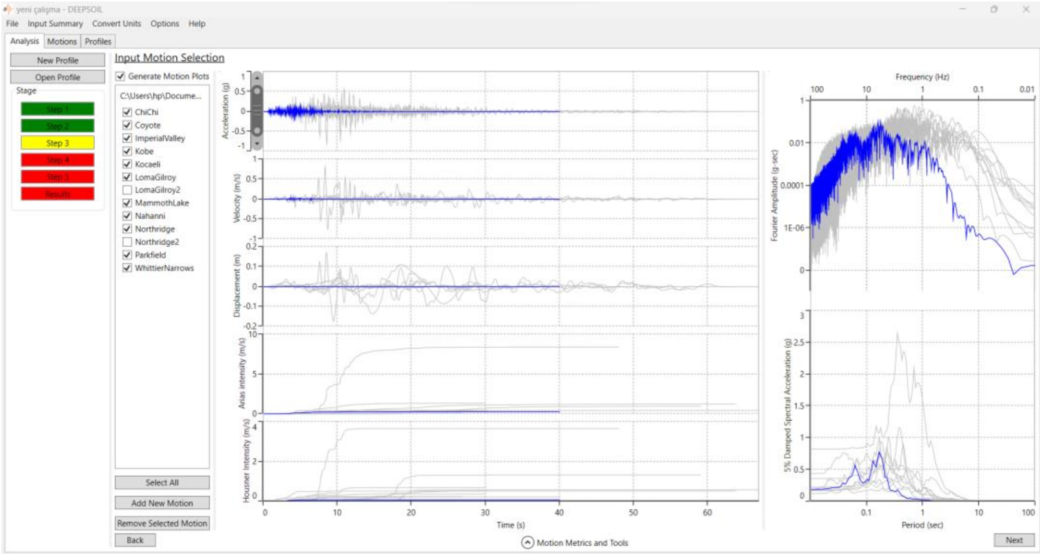


Figure 3.20. Selection of the scaled acceleration records

During the selection of earthquake records on the DeepSoil programme screen, the scaled version of these records was used. Analysis for all strata in the programme results or the programme with the selection of the desired layer depth to be observed results can be analysed (Figure 3.18).

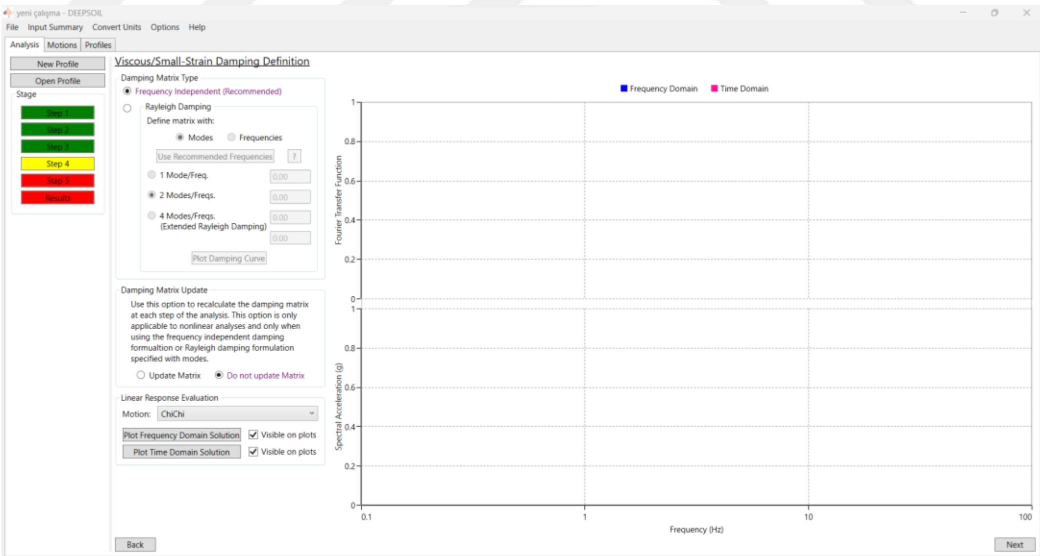


Figure 3.21. Selection of the desired depth for the effect of the acceleration record

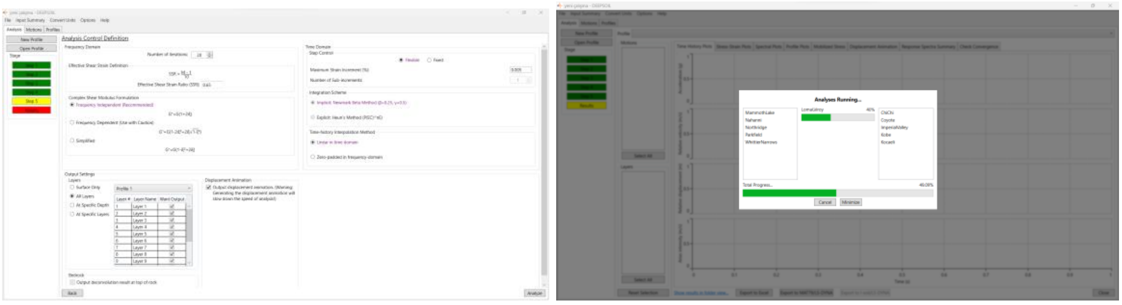


Figure 3.22. DeepSoil analysis for a selected earthquake records and a specified soil profile.

11 earthquake records were selected and their behaviour in the soil profile was investigated, and response analyses were completed with acceleration records at the end of the programme.

4. RESULTS AND DISCUSSION

4.1. Deepsoil Soil Strata Data Results

Figures 4.1 - 4.11 display the acceleration and response spectrum graphs obtained through the Deepsoil program. These graphs were used to calculate average spectrum values and horizontal displacement values, utilizing 11 earthquake records.

In Figure 4.1, the Chichi earthquake data reveals that the PSA (Peak Spectral Acceleration) reaches its highest peak within 0.8 seconds. The results of the acceleration analysis range between 0.2 and 1.4 g.

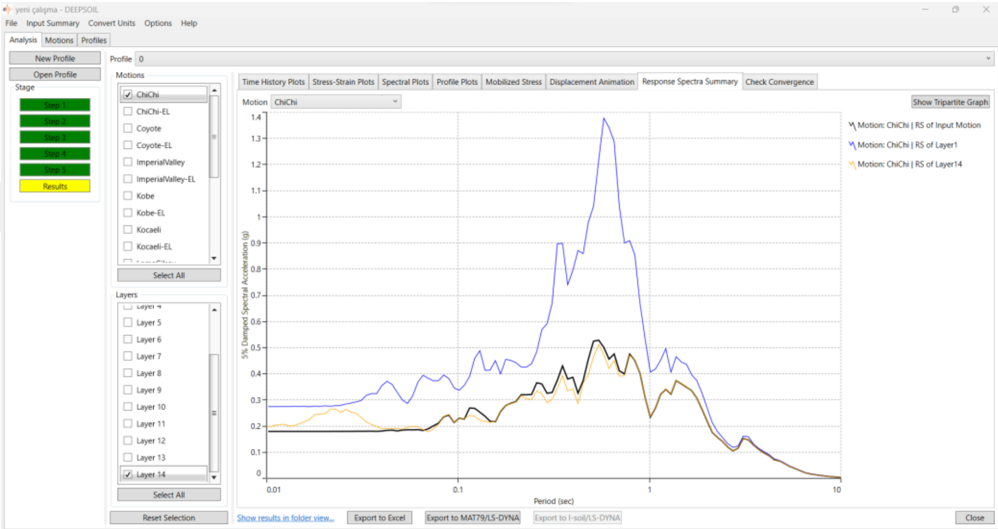


Figure 4.1. Site response analysis for Chichi Earthquake

Figure 4.2 illustrates the Coyote earthquake data, indicating that the PSA reaches its peak value within 0.6 seconds. The analysis of acceleration reveals a range of 0.1-1.3 g.

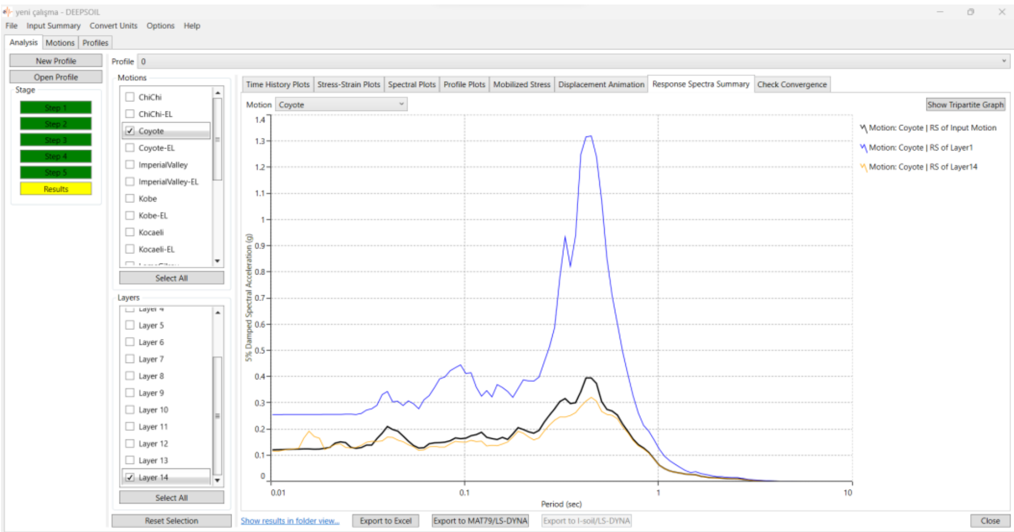


Figure 4.2. Site response analysis for Coyote Earthquake

Figure 4.3 displays the Imperialvalley earthquake data, demonstrating that the PSA reaches its highest peak within 0.7 seconds. The analysis of acceleration indicates a variation between 0.15 and 1.7 g.

Figure 4.3. Site response analysis for Imperialvalley Earthquake

In Figure 4.4, the Kobe earthquake data is presented, revealing that the PSA reaches its highest peak within 0.5 seconds. The acceleration analysis results display a range of 0.4-2.6 g.

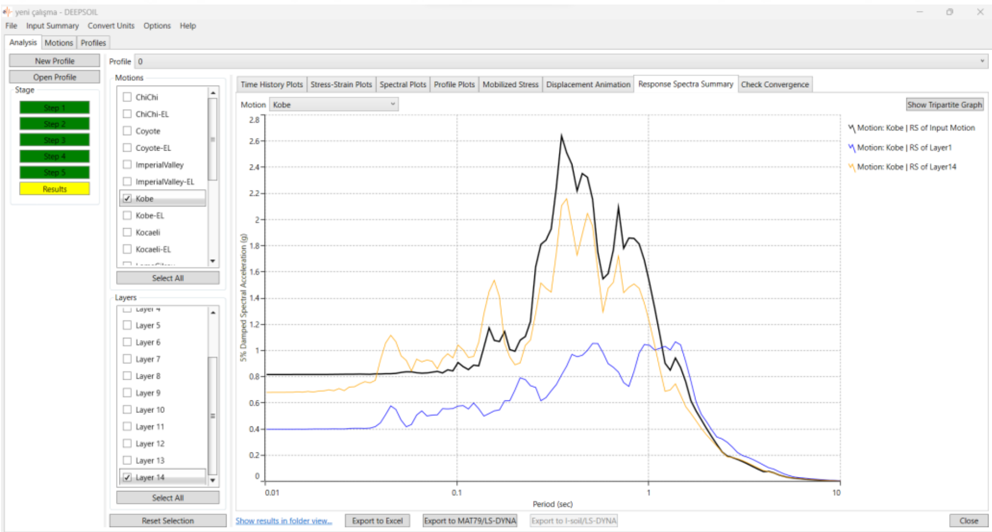


Figure 4.4. Site response analysis for Kobe Earthquake

In Figure 4.5, the Kocaeli earthquake data is depicted, indicating that the PSA reaches its maximum peak within 0.2 seconds. The analysis of acceleration reveals a range of 0.2-1.15 g.

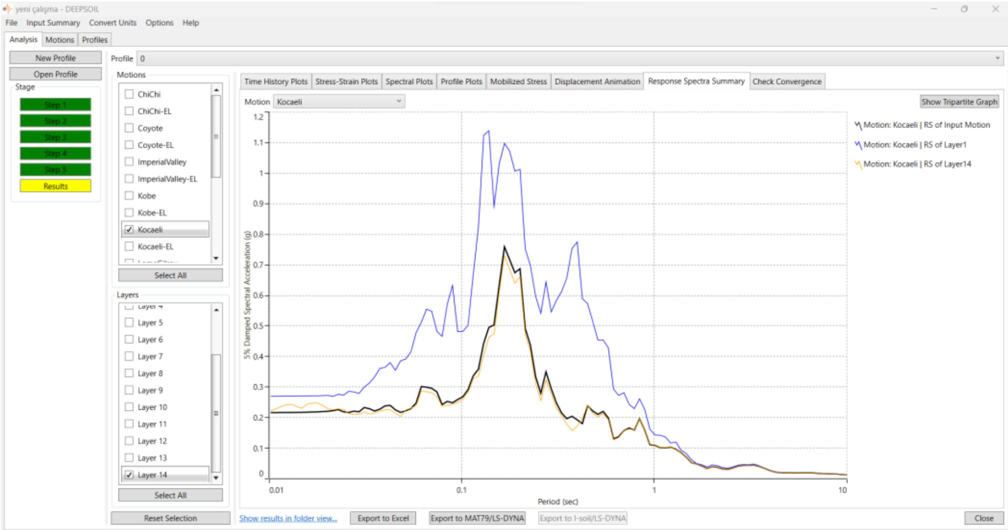


Figure 4.5. Ground response analysis for Kocaeli Earthquake

In Figure 4.6, the data for the Limagilroy earthquake is shown, revealing that the PSA reaches its maximum peak within 0.4 seconds. The analysis of acceleration results in a range of 0.2-1.10 g.

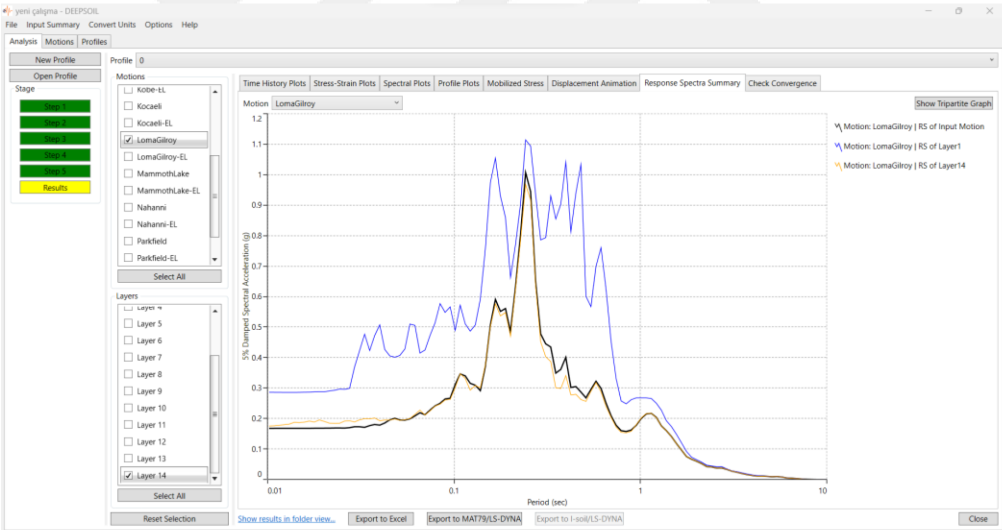


Figure 4.6. Site response analysis for Limagilroy Earthquake

Figure 4.7 displays the earthquake data for Mammoth Lake, indicating that the PSA reaches its highest peak in 0.7 seconds. The analysis of acceleration reveals a range of 0.4-1.90 g.

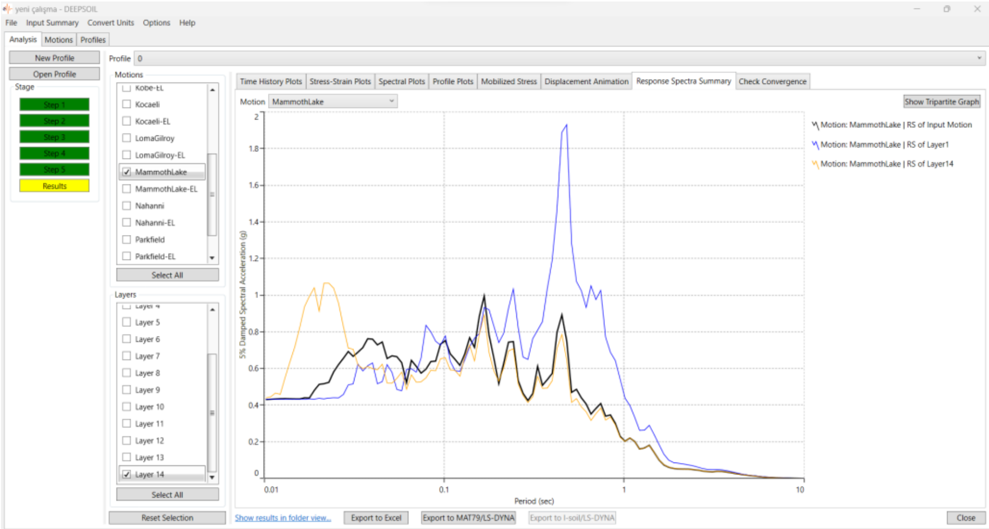


Figure 4.7. Site response analysis for MammothLake Earthquake

The Nahanni earthquake data is depicted in Figure 4.8, illustrating that the PSA reaches its highest peak within 0.08 seconds. The analysis of acceleration reveals a range of 0.15-1.10 g.

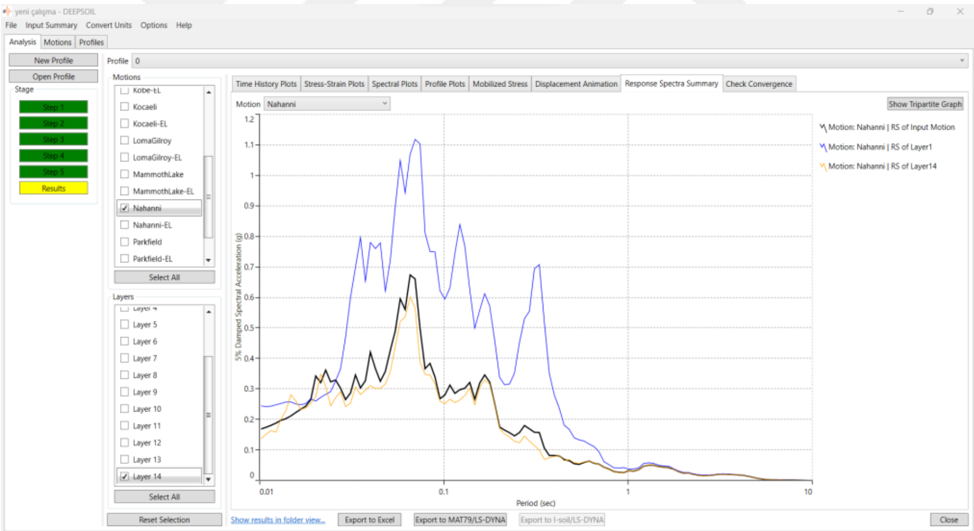


Figure 4.8. Site response analysis for Nahanni Earthquake

The Northridge earthquake data is presented in Figure 4.9, indicating that the PSA reaches its highest peak within 0.4 seconds. The analysis of acceleration reveals a range of 0.2-1.00 g.

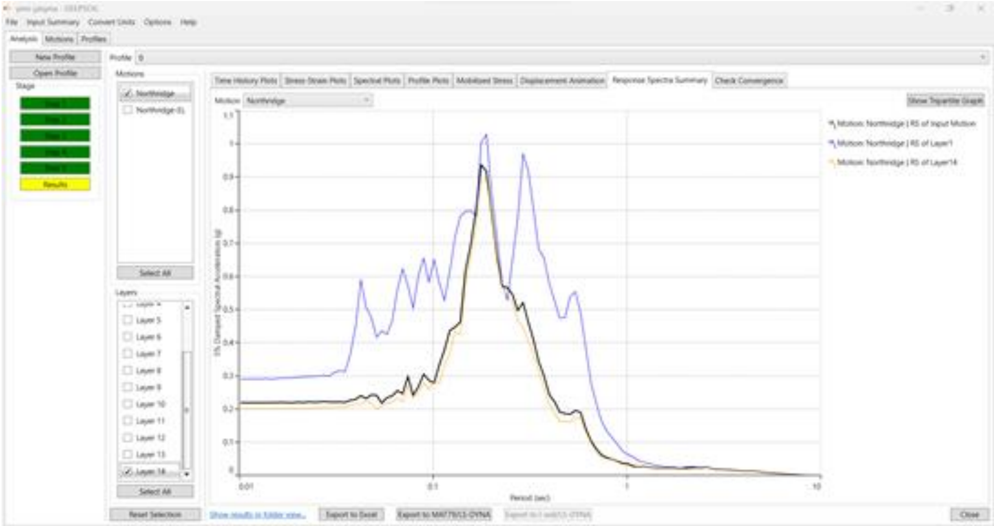


Figure 4.9. Site response analysis for Northridge Earthquake

The Parkfield earthquake data is displayed in Figure 4.10 showing that the PSA reaches the maximum peak within 0.4 seconds and the accelaration analysis results varies between the range of 0.2-1.10 g.

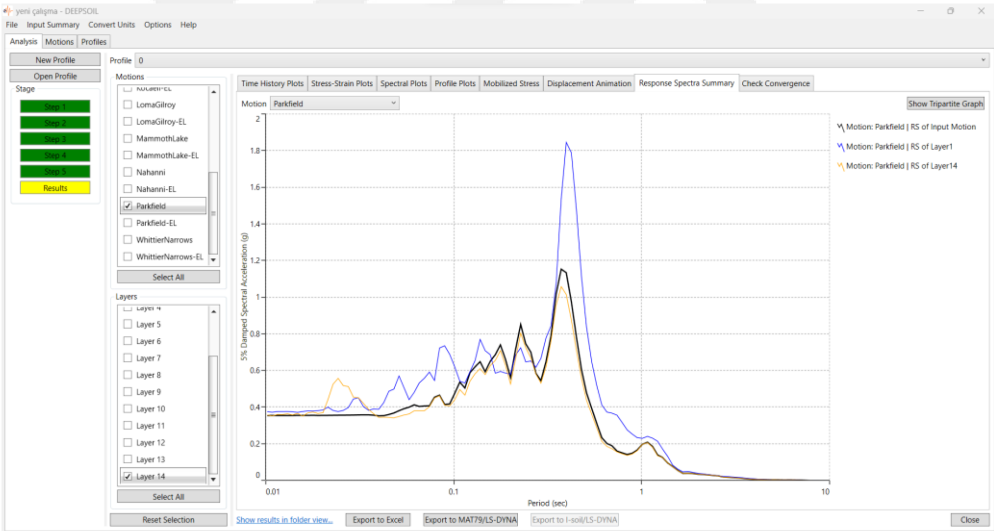


Figure 4.10. Site response analysis for Parkfield Earthquake

Figure 4.11 displays the earthquake data for Mammoth Lake, indicating that the PSA reaches its highest peak in 0.2 seconds. The analysis of acceleration reveals a range of 0.2-1.50 g.

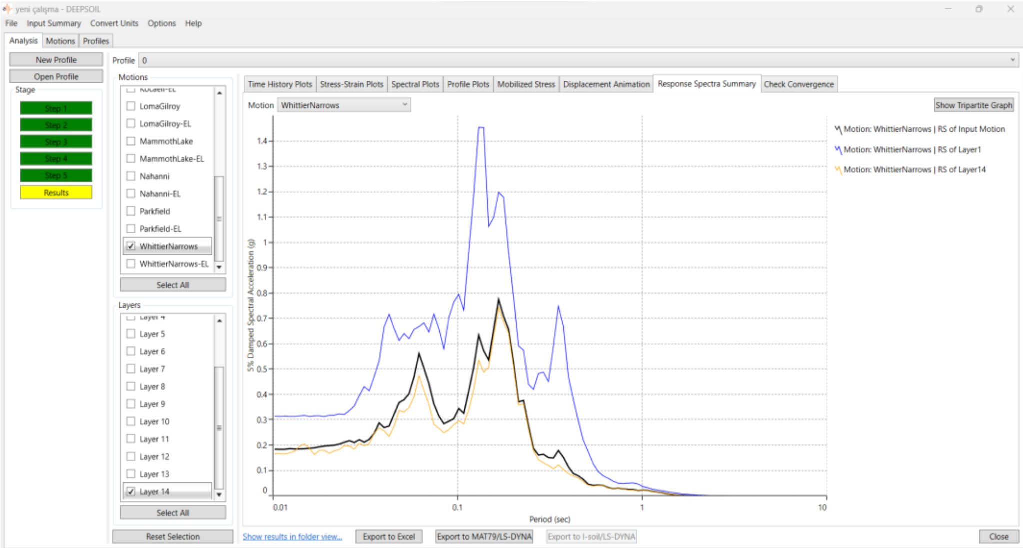


Figure 4.11. Site response analysis for WhittierNarrows Earthquake

Figure 4.12 displays the horizontal displacements of 11 earthquakes computed by the Deepsoil programme calculations. The average displacement was determined to be 4 cm. However, the Kobe earthquake had a significantly high value of 23 cm, which deviates from the normal values.

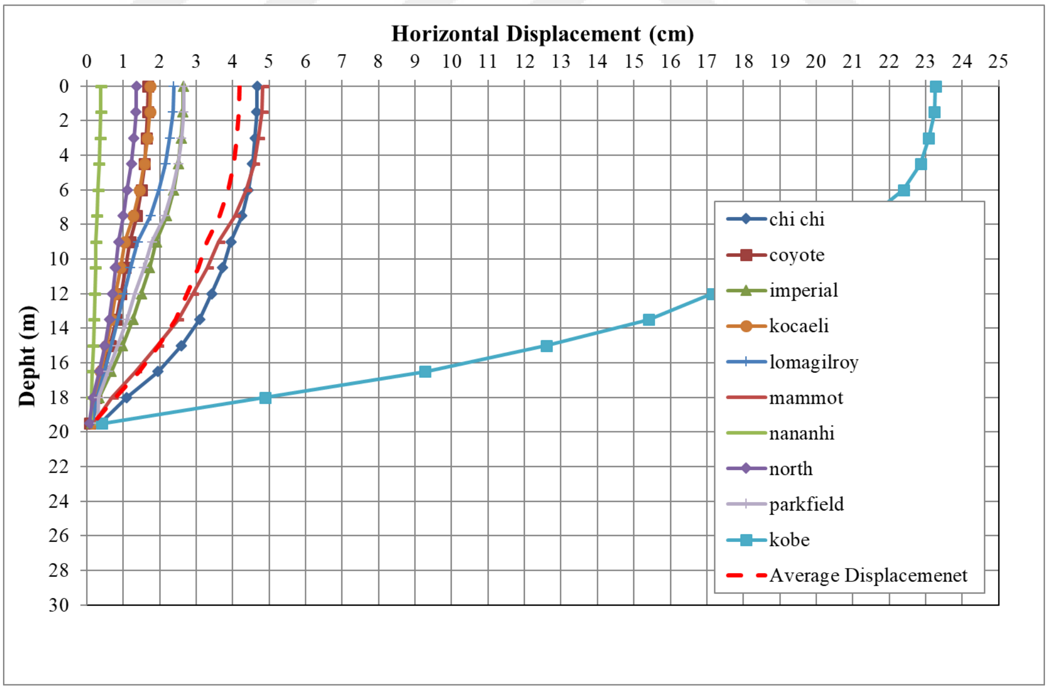


Figure 4.12. Plot of 11 earthquakes and their horizontal displacement

Figure 4.13 presents the results obtained through the Deepsoil programme, indicating that the average spectrum demonstrates the PSA reaching its highest peak in 0.4 seconds. Moreover, the analysis of acceleration displays a range of 0.4-1.4 g.

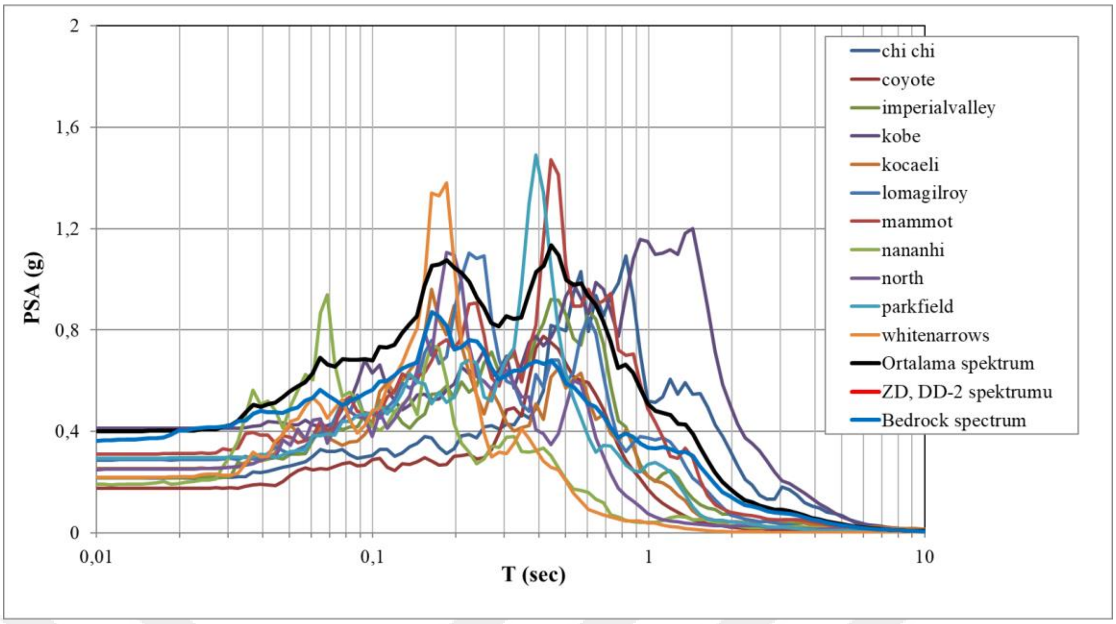


Figure 4.13. Plot of 11 earthquakes, their average and the PGA of the bedrock

4.2. Envelope Curve of the Study Area According to TBDY

Data gained from the AFAD's Earthquake Hazard Interactive Map Web Application

SS : Short period map spectral acceleration coefficient (dimensionless)

S1 : Map spectral acceleration coefficient for 1.0 second period (dimensionless)

PGA : Maximum ground acceleration (g)

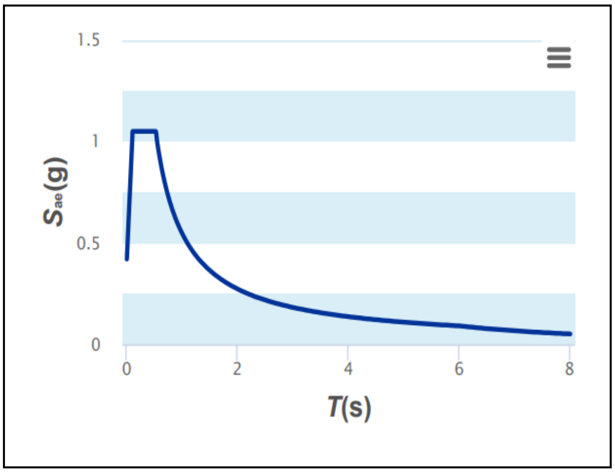
PGV : Maximum ground velocity (cm/sec)

Design Spectral Acceleration Coefficients

$S_{DS} = S_S F_S$ $S_{D1} = S_1 F_1$

S_{DS} : Short period design spectral acceleration coefficient (dimensionless)

S_{D1} : Design spectral acceleration coefficient for 1.0 second period (dimensionless) (AFAD)



$$S_{ae}(T) = \left(0.4 + 0.6\frac{T}{TA}\right) S_{DS} \quad (0 \le T \le T_A) \qquad \textbf{4.1}$$

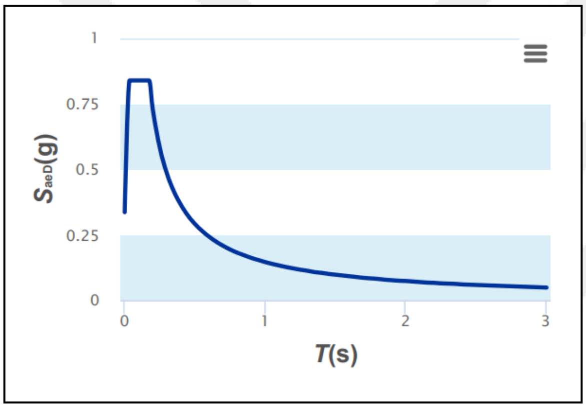
$$S_{ae}(T) = S_{DS} \quad (T_A \le T \le T_B) \qquad \textbf{4.2}$$

$$S_{ae}(T) = \frac{S_{D1}}{T} \quad (T_B \le T \le T_L) \qquad \textbf{4.3}$$

$$S_{ae}(T) = \frac{S_{D1} T_L}{T^2} \quad (T_L \le T) \qquad \textbf{4.4}$$

$$T_A = 0.2\frac{S_{D1}}{S_{DS}} \;;\quad T_B = \frac{S_{D1}}{S_{DS}} \;;\quad T_L = 6s \qquad \textbf{4.5}$$

Figure 4.14. Horizontal Elastic Design Spectrum (URL6)



$$S_{aeD}(T) = \left[0.32 + 0.48\frac{T}{T_A}\right] S_{DS} \quad (0 \le T \le T_{AD}) \qquad \textbf{4.6}$$

$$S_{aeD}(T) = 0.8\, S_{DS} \quad (T_{AD} \le T \le T_{BD}) \qquad \textbf{4.7}$$

$$S_{aeD}(T) = 0.8\, S_{DS} \frac{T_{BD}}{T} \quad (T_{BD} \le T \le T_{LD}) \qquad \textbf{4.8}$$

$$T_{AD} = \frac{T_A}{3} \;;\quad T_{BD} = \frac{T_B}{3} \;;\quad T_{LD} = \frac{T_L}{2} \qquad \textbf{4.9}$$

Figure 4.15. Vertical Elastic Design Spectrum (URL6)

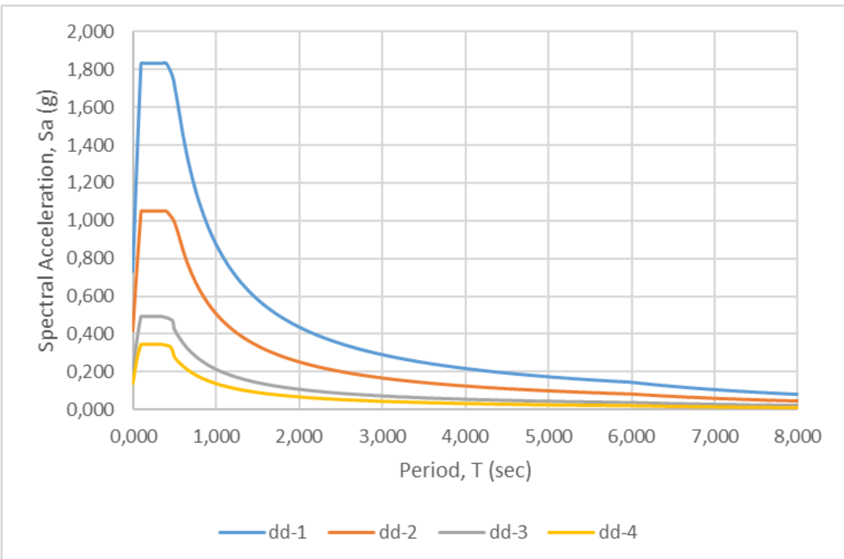


Figure 4.16. Representation of Bedrock Spectrum with Earthquake Envelope Curves

Figure 4.16 shows the average values of DD-1, DD-2, DD-3 and DD-4 taken separately from each of the plots/parcels where the boreholes in the study area are located in Sürsürü Neighbourhood.

4.3. Soil Maps Depending on Field and Laboratory Results

In addition to the study, V_{S1}, V_P / V_S, V_{S30}, T_0 and A_0 maps were drawn with field and laboratory results in order to better interpret the field.

4.3.1. Maps of Shear Wave Velocity for Corrected Stresses (V_{S1})

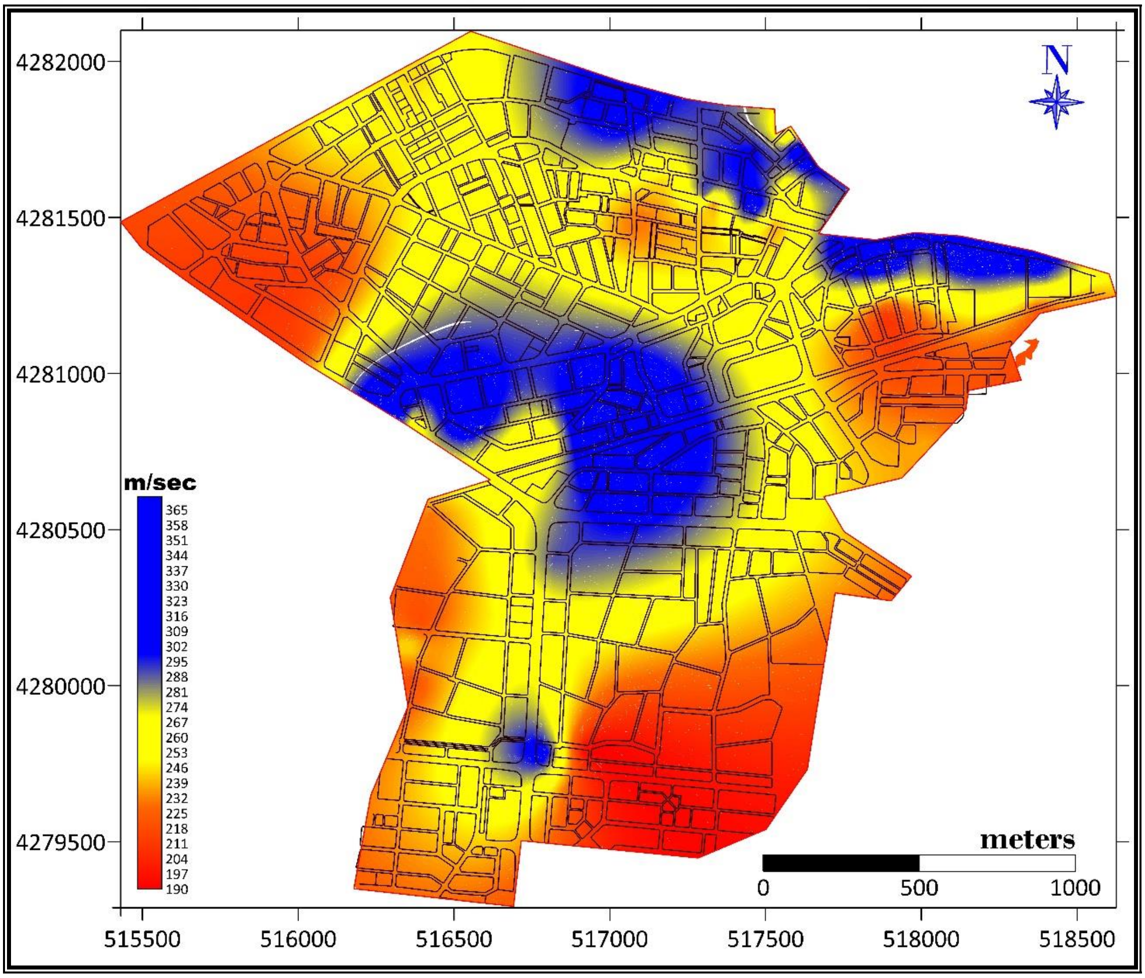


Figure 4.17. Map of shear wave velocity of the study area

Table 4.1. Classification of cohesive and cohesionless soils according to V_S velocities (Özaydın, 1982)

Cohesive Soils		Cohesionless Soils	
V_s (m/sec)	Ground Condition	V_s (m/sec)	Ground Condition
<200	Soft-Medium Solid	**<300**	Loose
200-300	Solid	**300-600**	Medium Dense
300-500	Very Solid	**600-800**	Dense
500-750	Hard	**800-1000**	Very Dense

From the seismic records taken in the investigation area, it was observed that the S wave velocity of the rises up to 2-10 m in average in the investigation area; the velocity values taken in the surfaced residual soils and coarse-grained alluvium, Vs velocities are higher than the areas where loose alluvium units are surfaced.

Vs velocities found as a result of the measurements taken in the study area, according to the classification of cohesive soils given by Özaydın (1982), V_{S1} velocities in the red-orange-yellow coloured areas on the map are in the range of 190-290 m/sec in the units located up to a depth of 2-9 m on average, and it is seen that it is classified as **"soft-medium solid, solid"** soils according to cohesive soils. In addition, the V_{S1} velocities of the soils in the blue coloured sections in the map are in the range of 291-365 m/sec and it is seen that they are classified as **"solid-very solid"** soils according to cohesive soils.

4.3.2. Map of Seismic Velocity Ratio (V_P / V_S Ratio)

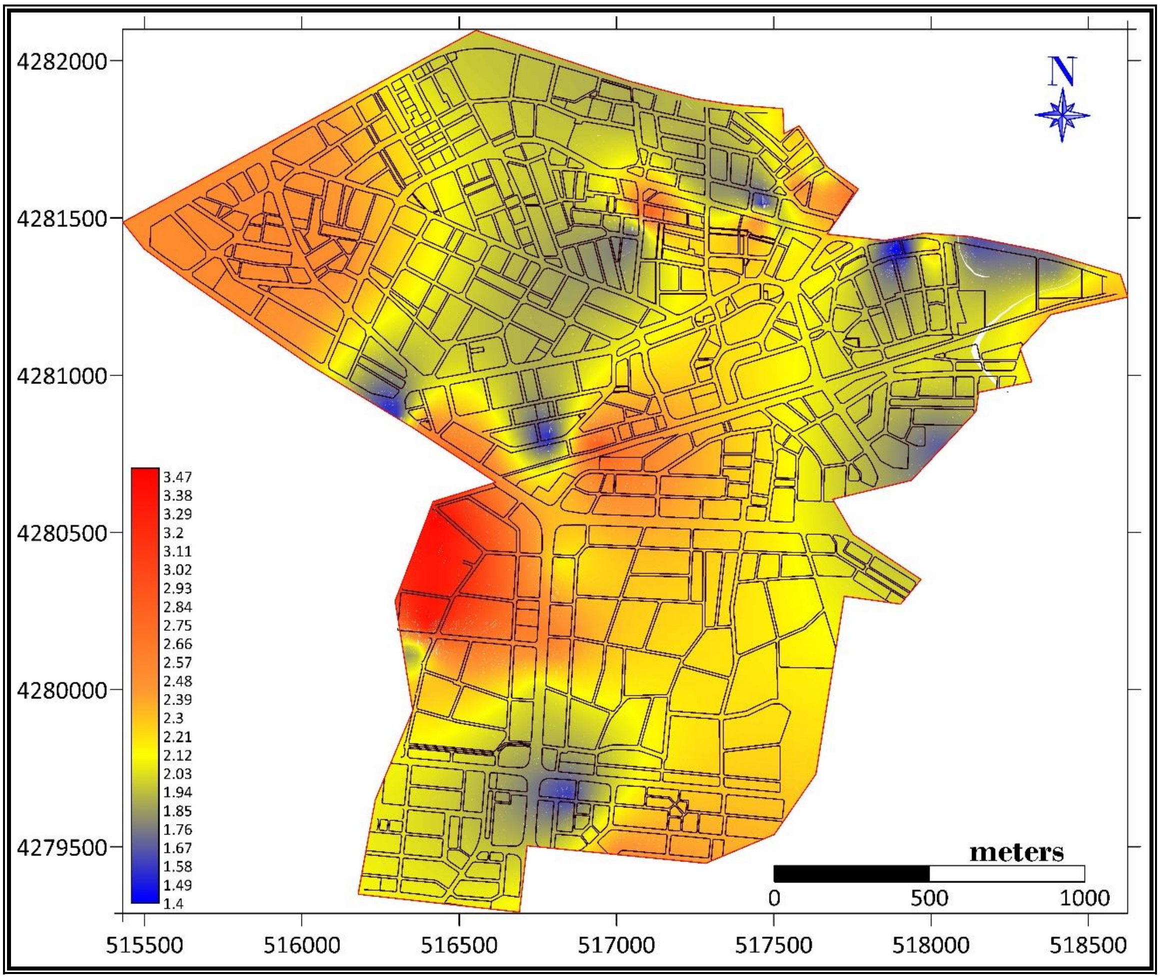


Figure 4.18. Map of seismic velocity ratio of the study area

In recent years, seismic velocity ratio has been used in soil studies, especially to determine the density of alluvial soil. this safety coefficient (V_P/V_S) is calculated as the ratio of seismic pressure wave velocity (V_P) to shear wave velocity (V_S). The change in the V_P/V_S ratio gives us information about the condition of the ground. These values vary between 1.5 in very dense, stiff environments that are not saturated with groundwater and 5-8 in loose environments saturated with groundwater (Keçeli, 2010). The similarity between (V_P/V_S) ratio and soil type is shown in Table 4.2. The table of Keçeli (2010) was used to evaluate the V_P/V_S ratio

Table 4.2. Seismic velocity ratio (V_P/ V_S) according to soil type (Keçeli, 2010)

Soil Type	(V_P/V_S)
Hard and massif rocks	1.45-1.50
Very stiff	1.50-2
Stiff	2-3
Moderate stiff but altered	3-4
Loose and soft	4-6
Soft and saturated	5-8

In addition, using V_P/V_S values, preliminary information about soil liquefaction; hydrocarbon reservoir evaluations in soil layers; soil behaviour in microzoning the local effects of any earthquake, determination of soil magnification and classification of the soil; aquifers can be studied in many areas such as examination (Keçeli, 2010).

The V_P/V_S ratios calculated in the study area (for the surface layers) were mapped. When the V_P/V_S ratio maps of the sections close to the surface are examined according to the classification of Keçelinin; the blue-yellow coloured sections in the study area are in the class of **hard/massif rocks - very stiff** environments and the orange-red coloured sections are in the class of **stiff - moderate stiff but altered** degraded environments.

4.3.3. Map of Shear Wave Velocity According to 30 m Depth (V_{S30})

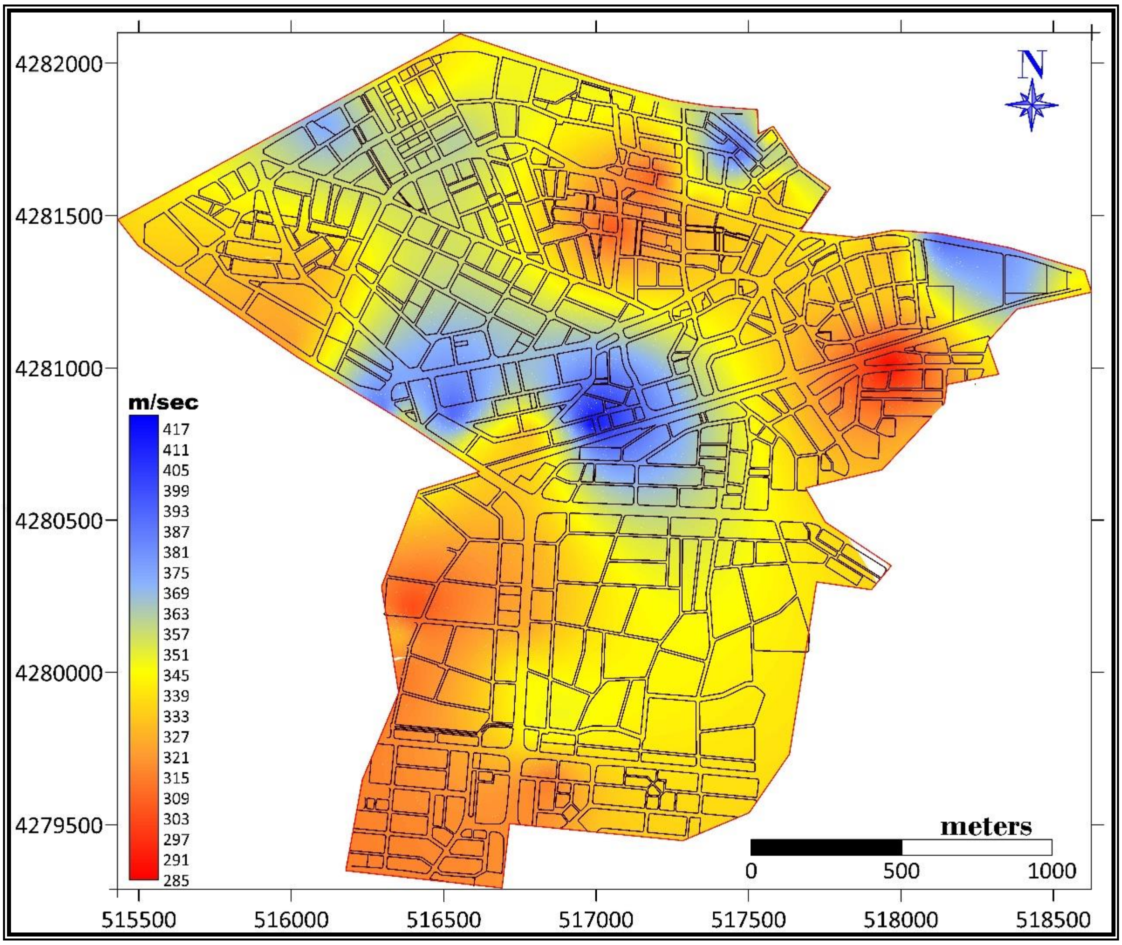


Figure 4.19. Map of V_{S30} distribution according to seismic results of the study area

The soil classification of the units observed in the study area was made by using the " V_{S30} velocity" values obtained from geophysical measurement data. For this classification, according to the Turkish Building Earthquake Regulations (Table 4.3), the soil classification table was used.

Local soil classes and soil groups of the study area were determined by evaluating the seismic studies together. According to the "Regulation on Structures to be Built in Disaster Zones (2019)" (Table 3.12), the loose soils in the study area are classified as soil class ZD since the Vs30 velocity range is **285-360 m/sec**, and the hard soil units and residual soil levels are classified as soil class ZC since the V_{s30} velocity range is **361-471 m/sec** for the parts shown in red-orange-yellow colour on the map.

4.3.4. Determination of Soil Amplification and Predominant Period

Seismic measurements were made in the project area and relative ground amplification values and site predominant vibration period values (T_0) were determined.

As it is known, in earthquakes, if the ground on which the structure sits vibrates or in other words shakes, the engineering structure also oscillates. In the event of an earthquake, if the period of the engineering structure and the ground on which it sits are close to each other, the damage is higher than expected due to resonance.

The magnitude of the energy transferred from the ground to the structure depends on the magnitude of the intensity at that point and the proximity of the "natural period of the structure" to the "dominant period of the ground". Therefore, the distance of the "natural" periods of the structure from the "dominant" period of the ground, in other words, "structure-ground compatibility" is a very important key in combining safety and economy, which is an engineering objective (Aytun, 2001).

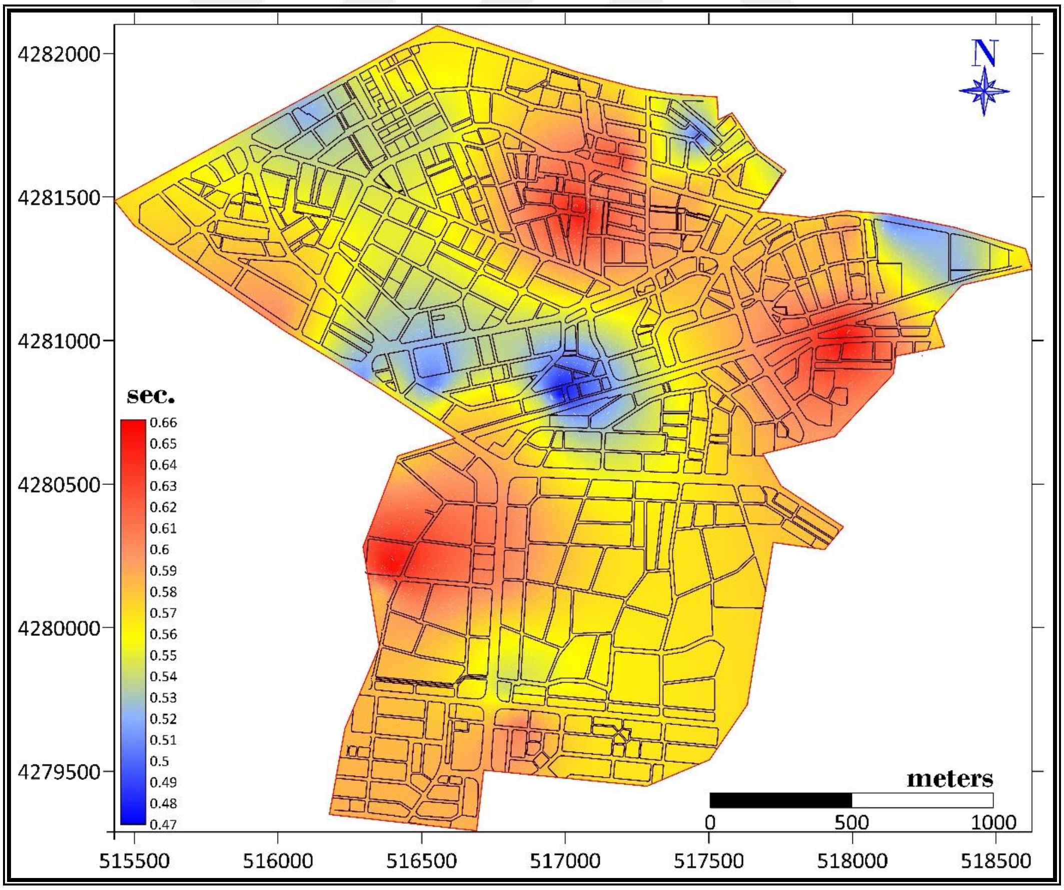


Figure 4.20. Map of site dominant vibration period

As a result of the examination of the site dominant vibration period distribution map given in Figure 4.20 (Ansal et al., 2004), according to Table 3.8, it is observed that the blue coloured parts of the map (T_0:0.47-0.50) of the hard soils and residual soil units surfacing in the study area are classified as **"B, medium hazard level"** in terms of site dominant vibration period, and the light blue-yellow-orange-red coloured parts of the map (T_0:0.51-0.66) where loose soil units are located are classified as **"C, high hazard level".**

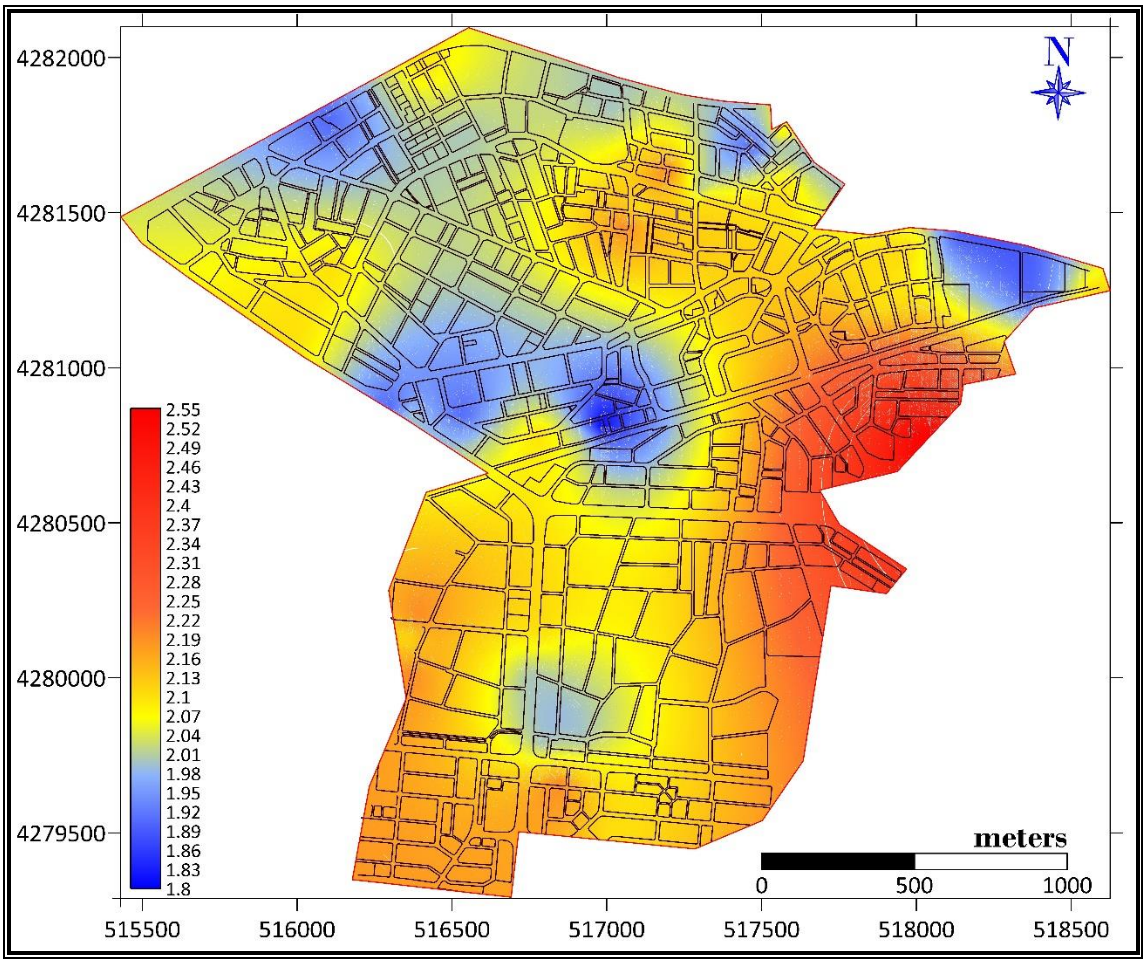


Figure 4.21. Map of seismic amplification of the study area

Earthquake waves cause magnification at various rates depending on the characteristics of the ground on which they occur. It is known that the damage in soft soils is higher than in hard soils due to this magnification ratio. In addition, this magnification causes the earthquake intensity to increase. Relative soil magnification (Akm) values from S-wave are found by using various approaches and considering these values, building dimension and foundation analyses are performed by paying attention to geotechnical problems and building calculations are performed by adhering to the principles of earthquake resistant building design. According to the approach of Ansal et al. (2004), the relative soil magnification factors for the units surfacing in the study area are calculated to vary in the range of **“1.8 ≤ A_{kM} ≤ 2.55”** for the units surfacing in the study area. As a result of examining the soil amplification distribution map given in Figure 5 by considering the classification of Ansal et al. (2004); it is observed that the blue-yellow-orange coloured areas in the study area are classified as **"A, low hazard level"** and the red coloured areas are classified as **"B, medium hazard level"**.

4.3.5. Spectral Acceleration at Short Period

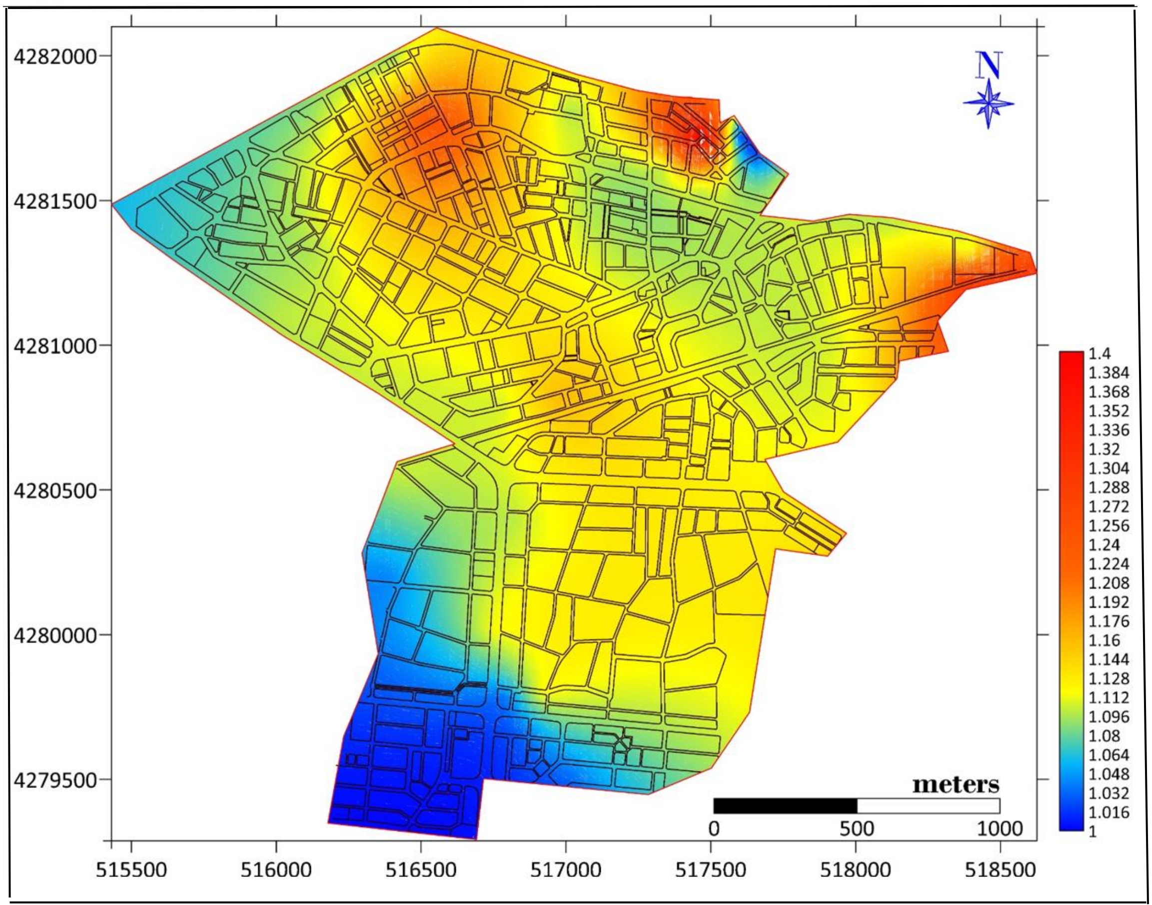


Figure 4.22. Map of spectral accelerations of the study area

The spectral accelerations in the rock and on the surface, which is simply V_P /V_S, standing fort the ground amplification, and it is predicted that if the surface spectra are large where the amplification is high, the ground shaking will be felt more there. It has been determined with the spectral accelerations calculated that the surface accelerations in the upper right corner of the map of Sürsürü District are more in the upper right corner and less in the lower left corner.

5. CONCLUSIONS

The main purpose of this study is to present the findings and results regarding the seismic impact of the earthquake with the goal of minimizing its impact in the future and providing recommendations based on seismic parameters. The Elazig-Sürsürü neighborhood, which consists mainly of young sediments classified as brown gravelly sandy clay with a groundwater table below 15 meters, suffered significant structural damage. To conduct this study, geotechnical and geophysical data were collected from 72 boreholes to create an idealized soil profile of the Sürsürü district. The study was conducted in two stages, starting with seismic site response analyses using the DEEPSOIL (7.0) software. Subsequently, the collected seismic parameters were utilized to create seismic site zoning maps using geographic information system (GIS). Moreover, the study aimed to create maps showing the site's dominant vibration period (T_0), shear wave velocity (Vs_{30}), and velocity ratio (Vp/Vs). As part of the study's conclusion, a specific seismic hazard assessment was developed for the Elazig-Sürsürü neighborhood. Based on the data obtained in the study, several conclusions were drawn.

i) The calculated mean of the spectral accelerations of the site-specific earthquake ground motions determined by Deepsoil meets the condition stated in TBDY-2018 in 2.4.1.2 "The ordinates of the site-specific earthquake ground motion spectra shall never be smaller than 90% of the ordinates of the design spectrum defined in TDBY chapters 2.3.4 or 2.3.5." The site dominant vibration period varies between 0.2 seconds and 0.7 seconds, indicating that 2 to 7 storey buildings can experience resonance according to the formula H=T/Cn, where Cn=0.1 for reinforced concrete structures. In this formula, H represents the number of storeys in the building and is related to amplifications in the ground.

ii) As per the Deepsoil software, TBDY requires the utilization of at least 11 sets of earthquake ground motion in linear calculations. These calculations are carried out using the Mode Summation Method in the time domain. The acceleration recordings in two mutually perpendicular horizontal directions, corresponding to the (x) and (y) principal axes, should be simultaneously applied to the structural system. Based on the study's calculations, the Coyote earthquake had the highest soil amplification among the 11 earthquakes, measuring 4.3, while the Kobe earthquake had the lowest soil amplification at 0.71. The presence of amplification and high spectral accelerations can result in a high damage.

iii) According to the map displaying short-term spectral accelerations, the northern part of the Sürsürü neighborhood, including Mustafa Uygur Boulevard, Nurettin Ardıçoğlu Cultural Centre, and Atatürk Boulevard, as well as the vicinity of Hıdır Sever Anatolian High School, exhibit high surface accelerations. Additionally, there are elevated short-term spectral accelerations in the area stretching from Cihan Street towards Imam Efendi Boulevard. Accordingly, the same areas with high seismic velocity ratios (V_P/V_S) and short-period spectral accelerations will experience more severe ground shaking. The area from the vicinity of Cihan Caddesi towards İmam Efendi Boulevard is identified as having moderate to high values in both maps. It is of great importance to pay attention to the amplifications in this area and to carry out more comprehensive geotechnical investigations with better quality boreholes.

iv) Based on the analysis of 11 earthquakes, the average horizontal displacement is determined to be 4 cm, which falls within an acceptable range

v) Based on the results obtained from the Kobe Earthquake, it is observed that the displacement of 23 cm exceeds the allowable limits. This indicates that the ground deformation caused by the earthquake may influence the frequency content and potentially lead to resonance.

vi) The shear wave velocity ranges from 190 to 365 m/sec, the Vp/Vs ratio ranges from 1.9 to 3.45, and the T_0 ranges from 0.47 to 0.66. When comparing the maps for these three data sets, the areas at higher risk of liquefaction are identified by low shear wave velocity and high Vp/Vs and T_0 values. Specifically, the area encompassing Imam Efendi Boulevard, Malatya Street, and Mustafa Uygur Boulevard (located in the upper left corner on the map), the region around Imam Efendi Boulevard-Total Imam Efendi (found in the left middle section of the map), and the vicinity of Fırat Port Headquarters (situated in the upper middle right on the map) are at a heightened risk due to their full saturation.

vii) The groundwater level varies between 3 meters and 16 meters, with areas where groundwater is not encountered. The northeastern part of the neighborhood, particularly around the Fırat Liman Başkanlığı, exhibits groundwater at 3 meters, while moving southward towards Elazığ Çevre Yolu, the groundwater level ascends to 16 meters. Considering the high surface water and groundwater levels during heavy rainfall periods, drainage measures and methodologies should be planned and specified to prevent adverse effects on the construction foundation and substructure, which are intended to be built based on these conditions.

REFERENCES

Adar, K., Büyüksaraç, A., Işık, E., & Ulu, A.E. (2021). 2007 ve 2018 Deprem Yönetmeliklerinin Yapısal Analizler Işığında Karşılaştırılması. Avrupa Bilim ve Teknoloji Dergisi, (25), 306-317.

Afacan K.B. , Güler E., (2019). Yeni Deprem Yönetmeliği Performansının Zemin Büyütme Analizi ile Belirlenmesi. 5. International Conference on Earthquake Engineering and Seismology (5ICEES). ResearchGate. (https://www.researchgate.net/publication/336983424)

Akın, M.K., Akın, M., Özvan, A., Akkaya, İ., (2015). Mikrobölgeleme Çalışmasına Altlık Oluşturmak Üzere Van Yüzüncü Yıl Üniversitesi Kampüs Zemininin Dinamik Özelliklerinin Belirlenmesi. Jeoloji Mühendisliği Dergisi 39 (1) 2015. ResearchGate. (https://www.researchgate.net/publication/314716653)

Aki, K., Richards, P.G., (1980). Quantitative Seismology, Theory and Methods. Volume I: 557 pp., 169 illustrations. Volume II: 373 pp., 116 illustrations. San Francisco.

Ali, E.M., Osman, M.A., Abuelhassan M.B., (2012) Field Measurement of Shear Modulus of Hard Clays ; A case study of Kosti Thermal Power Plant Project, Sudan, Journal of BRR VOL 12 July 2012, 37-5

Alpan, I., 1967, The Empirical Evaluation of the Coefficient Ko and Kor, Soil and Foundation, Vol.3, No.1

Ansal, A. Editor (2004) Recent Advances in Earthquake Geotechnical Engineering and Microzonation, Kluwer Academic Publishers.

Ansal A, Tönük G, Kurtuluş A (2011) "Site Specific Earthquake Characteristics for Performance Based Design", Proc. of the 5th Int. Conf. on Geotechnical Earthquake Engineering, Santiago, Chile.

Aytun, A., (2001), "Olası deprem hasarını en aza indirmek amacıyla yapıların "doğal" salınım periyodlarının yerin "baskın" periyodundan uzak kılınması", Uşak İli ve Dolayı (Frigya) Depremleri Jeofizik Toplantısı, TMMOB Jeofizik Mühendisleri Odası, Ankara.

Başokur, A.T., (2002). Doğrusal ve Doğrusal Olmayan Problemlerin Ters-Çözümü. Jeofizik Mühendisleri Odası Eğitim Yayınları, Ankara.

Bayrak, E., Ozer, C. The 24 January 2020 (Mw 6.8) Sivrice (Elazig, Turkey) earthquake: a first look at spatiotemporal distribution and triggering of aftershocks. Arab J Geosci 14, 2445 (2021).

Bolisetti, C., Whittaker, A. S., Mason, H. B., Almufti, I., Willford, M. (2014). Equivalent linear and nonlinear site response analysis for design and risk assessment of safety-related nuclear structures. Nuclear Engineering and Design, 275, 107–121.

Borcherdt, R.D. (1970). Effects of local geology on ground motion near San Francisco Bay. Bulletin of the Seismological Society of America, 60(1), 29-61.

Church, H.K., (1981) Excavation handbook. McGraw-Hill Inc., New York.

Civelekler E., Okur D.V., Afacan K.B., (2018) Eşdeğer Analiz Yöntemi ile Zeminin Dinamik Davranışının Değerlendirilmesi: Eskişehir. Eskişehir Teknik Üniversitesi Bilim ve Teknoloji Dergisi B - Teorik Bilimler 6 - 124–132.

Civelekler, E., Okur, V.D., Afacan, K.B., (2021), A study of the local site effects on the ground response for the city of Eskişehir, Türkiye. Bulletin of Engineering Geology and the Environment volume 80, pages5589–5607 (2021).

Civelekler, E., Afacan, K.B.,(2022). Effect of Site Specic Soil Characteristics on the Nonlinear Ground Response Analysis. Research Square. (https://doi.org/10.21203/rs.3.rs-2193831/v1)

Çabalar , A.F., Canbolat A., Akbulut , N., Tercan S.H., Isika H., (2019). Soil liquefaction potential in Kahramanmaras, Türkiye. July 2019 Geomatics, Natural Hazards and Risk 10(1):1822-1838 DOI:10.1080/19475705.2019.1629106.

Çetin, H.; Güneyli, H.,(2001) Doğu Anadolu Fay Sisteminin Palu-Hazar Gölü ve Hazar Gölü-Sincik Segmentlerinin Paleosismisitesi. TÜBİTAK. Proje No: YDABÇAG-550.

Darendeli, M. B. (2001). "Development of a new family ofnormalized modulus reduction and material damping curves," Ph. D., University of Texas at Austin.

Doğancı, K., (2019) Hellespontos ve Çevresini Etkileyen Depremler (MÖ 3000-MS 6. YY). History Studies, 11/2, Nisan 2019, s.535-555.

Duman T.Y., Emre Ö. 2013. The East Anatolian Fault: geometry, segmentation and jog characteristics. Geological Society, London, Special Publications, 372(1):495-529.

EC8 (2004) EN 1998–1 (2004): Eurocode 8: Design of Structures for Earthquake Resistance – Part 1: General Rules, Seismic Actions and Rules for Buildings. European Committee for Standardization (CEN), Brussels, Belgium

Ekinci, A. (2011). "Zemin iyileştirme yöntemleri, zemin etüdü ve uygulama alanları (Site improvement techniques applied in North Cyprus)". Kıbrıs Teknik Dergisi, 1, (1) 11-13, ISSN:1986-440X available from: (http://kibristeknik.com/kt-dergi-sayi1-ocak-2012/)

Elibüyük, M.; Yılmaz, E., (2010) Türkiye'nin Coğrafi Bölge ve Bölümlerine Göre Yükselti Basamakları ve Eğim Grupları. Coğrafi Bilimler Dergisi (CBD) 8 (1), 27-55 (2010).

Erener, M.F. , Hızal, Ç., Erdoğan, D.Ş., Sezer, A., Nuhoğlu, A., Ercan, E., Kıncal, C., Akgün, M., Özdağ, Ö.C., (2021). Geotechnical and Structural Assessmentof the Damages in Bayraklı Region After Samos 2020 Earthquake. 6 th International Conference on Earthquake Engineering and Seismology 13-15 October 2021 – GTU – Gebze, Kocaeli / Türkiye. ResearchGate. (https://www.researchgate.net/publication/355888035)

Erol, A.O, Çekinmez, E., (2014).Geoteknik Mühendisliğinde Saha Deneyleri. Yüksel Proje Yayınları No: 14 -01. Ankara 2014.

Gazetas, G., Dakoulas, P., And Papageorgiou, A., 1990, Local-soil and source-mechanism in the 1986 Kalamata Earthquake, Earthquake Engg, and Str. Dyn., 19, 431-456.

Groholski, D., Hashash, Y., Kim, B., Musgrove, M., Harmon, J., and Stewart, J. (2016). "Simplified Model for Small-Strain Nonlinearity and Strength in 1D Seismic Site Response Analysis". J. Geotech. Geoenviron. Eng., 10.1061/(ASCE)GT.1943-5606.0001496, 04016042.

Gündüz, A., Türkmen, S., Eryiğit, U., Karaca, Y., Aydın, M., (2012)"Is Turkey an earthquake country?/Turkiye bir deprem ulkesi midir?" The Journal of Academic Emergency Medicine, vol. 12, no. 1, Mar. 2013, pp. 33-37.

Güzel, M., (2009) Mikrobölgeleme Çalışmalarında Jeolojik, Jeofizik, Jeoteknik verilerin Birlikte Kullanımı (Kuzey Adana Örneği). [Doktora tezi, Çukurova Üniversitesi]. Yüksek Öğretim Kurulu Ulusal Tez Merkezi. (Tez No: 244345).

Hashash, Youssef M. A.; Phillips, Camilo; and Groholski, David R., "Recent Advances in Non-Linear Site Response Analysis" (2010). International Conferences on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics. 8. NEHRP (National Earthquake Hazards Reduction Program)Recommended Seismic Provisions for New Buildings and Other Structures Volume I: Part 1 Provisions, Part 2 Commentary FEMA P-2082-1/ September 2020.

Irsyam, M., Hutapea, B. M., Imran, I., & Asrurifak, M. (2019). Determination of Site Amplification Deep Soil Layers using 1-D Site Response Analysis (Case Study: Jakarta City, Indonesia). Journal of Engineering & Technological Sciences, 51(6).

Iyisan, R. ve Hasal, M.E., (2007). The effect of ground motion characteristics to the dynamic response of alluvial valley models, 13th Asian Regional Conference on Soil Mechanics and Geotechnical Engineering, December 10-14, Kolkata,India.

İyisan, R. ve Haşal, M.E., (2006). Farklı deprem hareketinin ve yerel zemin sınıfının dinamik davranışa etkisi, ZMTM 11. Ulusal Kongresi Bildiriler Kitabı, K.T.Ü., Trabzon.

İyisan, R., Haşal, M.E., (2011) Zemin Büyütmesi ve Yerel Koşulların Spektral İvmeye Etkisi. İTÜ Dergisi/D Mühendislik, 10: 4, 47-56.

Kanai, K., (1983) Engineering Seismology, 251. University of Tokyo, Japonya.

Karagöz, Ş., (2005): Eskiçağ'da Depremler. Ege Yayınları: İstanbul.

Keçeli, A., 2010, "Sismik Yöntem İle Zemin Taşıma Kapasitesi Ve Oturmasının Saptanması". Uygulamalı Yerbilimleri Dergisi, vol. 9, no. 1, 2016, pp. 23-41.

Keçeli, A., 1990, The determination of the Bearing Capacity by means of the seismic method: Jeofizik 4, 83-92.

Kramer S.L., (1996), Geotechnical earthquake engineering, Prentice-Hall, New Jersey, USA, 708ss.

Kramer, S.L., Arduino, P., and Shin, H. (2009). "Development of performance criteria for foundations and earth structures," Proceedings, International Conference on Performance-Based Design in Earthquake Geotechnical Engineering, Invited Theme Lecture Paper, Tsukuba, Japan, 14 pp.

Menq, F.Y., 2003. Dynamic properties of sandy and gravelly soils. Ph.D. dissertation, The University of Texas at Austin.

Mihalić, S., Oštrić, M., Krkać , M.,(2011) Seismic microzonation: A review of principles and practice. GEOFIZIKA VOL. 28 2011. Review paper UDC 550.340. ResearchGate. (https://www.researchgate.net/publication/258699006)

MTA, (2011). 1/100000 Scaled Geological Maps of Turkey. In General Directorate of Mineral Research and Exploration; Department of Geological Research of General Directorate of MTA: Ankara, Turkey.

MTA, (2002). 1/500 000 scale geological maps of Turkey. General Directorate of Mineral Research and Exploration; Department of Geological Research of General Directorate of MTA: Ankara, Turkey.

Nakamura, Y. (1989). A method for dynamic characteristics estimation of subsurface using microtremor on the ground surface. Railway Technical Research Institute, Quarterly Reports, 30(1).

NEHRP (National Earthquake Hazards Reduction Program)Recommended Seismic Provisions for New Buildings and Other Structures Volume I: Part 1 Provisions, Part 2 Commentary FEMA P-2082-1/ September 2020.

Özaydın K., 1982, Zemin Dinamiği, Deprem Mühendisliği Türk Milli Komitesi Yayınları No:1 İstanbul.

Özdemir, M.A. ve İnceöz,M., (2003). "Doğu Anadolu Fay Zonunda (Karlıova-Türkoğlu Arasında) Akarsu Ötelenmelerinin Tektonik Verilerle Karşılaştırılması"; Afyon Kocatepe Üniv. Sosyal Bilimler Dergisi, Cilt 5, Sayı l,s.89-114, 2003.

Pajak, J.(2005). "Signal processing in the "Zhang Heng Seismograph" for remote sensing of impending earthquakes". 1st International Conference on Sensing Technology November 21-23, 2005 Palmerston North, New Zealand, 669-673.

Palutoğlu, M., (2014) Elazığ Kent Merkezinin Tektoniği, Depremselliği ve Mikrobölgelemesi. [Doktora tezi, Fırat Üniversitesi]. Yüksek Öğretim Kurulu Ulusal Tez Merkezi. (Tez No: 355727).

Palutoğlu, M., Tanyolu, E., (2006) Elazığ İl Merkezi Yerleşim Alanının Depremselliği. Fırat Üniv. Fen ve Müh. Bil. Dergisi. 18 (4), 535–546, 2006. ResearchGate. (https://www.researchgate.net/publication/334031679).

Park, C.B.; Miller, R.D.; Xia, J.; Ivanov, J.; Sonnichsen, G.V.; Hunter, J.A.; Good, R.L.; Burns, R.A.; Christian, H. Underwater MASW to evaluate stiffness of water-bottom sediments. Lead. Edge 2005, 24, 724–728.

Phillips, C., Hashash, Y. M., (2009). "Damping formulation for nonlinear 1D site response analyses." Soil Dynamics and Earthquake Engineering, 29(7), 1143–1158.

Phillips, C., Hashash, Y. M., Groholski, D.R., (2010). Recent Advances in Non-Linear Site Response Analysis.

Puri, N., Jain, A., Mohanty, P., and Bhattacharya, S.,(2018) Earthquake Response Analysis of Sites in Hayrana State Using DEEPSOIL Software. Procedia Computer Science Volume 125, Pages 357-366.

Roesset, J.M., 1977, Soil amplification in earthquakes, Numerical Methods in Geotechnical Engineering, C.S. Desai and J.T. Christian, eds., McGraw Hill, New York, Chapter 19, 639-682, ISBN 0-07- 016542-4.

Salem, H.S. (2000). Interrelationships among Water Saturation, Permeability and Tortuosity for Shaly Sandstone Reservoirs in the Atlantic Ocean, Energy Sources, 22, 333 – 345.

Sayın, E., Yön, B., Onat, O. et al. 24 January 2020 Sivrice-Elazığ, Turkey earthquake: geotechnical evaluation and performance of structures. Bull Earthquake Eng 19, 657–684 (2021).

Silahtar, A., (2021). Isparta Havzasının 1D Doğrusal Olmayan Zemin Tepki Analizi Yöntemi ile Değerlendirilmesi; 1914 Burdur (Ms: 7.0) Deprem Senaryosu. Araştırma Makalesi / Research Article, Doğ Afet Çev Derg, 2021; 7(2): 226-239, DOI: 10.21324/dacd.793810.

Sitharam, T. G, Anbazhagan P., (2008) Seismic Microzonation: Principles, Practices and Experiments. EJGE Special Volume Bouquet 8, 61.

Sönmez, M.E. (2011). Coğrafi Bilgi Sistemleri (CBS) tabanlı deprem hasar riski analizi: Zeytinburnu (İstanbul) örneği. Türk Coğrafya Dergisi, 56, 11-22.

Sönmezer, Y.B., Çeliker, M., Baş, S., (2019).An investigation on the evaluation of dynamic soil characteristics of the Elazig City through the 1-D equivalent linear site-response analysis. Bulletin of Engineering Geology and the Environment. Volume 78, Issue 7, 1 October 2019, Pages 4689-4712.

Taş, N. (2003). "Yerleşim alanlarında olası deprem zararlarının azaltılması". Uludağ Üniversitesi Mühendislik- Mimarlık Fakültesi Dergisi, 8(1), 225-231.

TBDY (Türkiye Binalarda Deprem Yönetmeliği) (2018) Afet ve Acil Durum Yönetimi Başkanlığı. Sayı : 30364 (Mükerrer).

Technical Committee for Earthquake Geotechnical Engineering, TC4, ISSMGE (1999) "Manual for Zonation on Seismic Geotechnical Hazards", The Japanese Geotechnical Society.

Telford, W.M., Geldart, L.P. and Keys, D.A. (1976) Applied Geophysics. Cambridge University Press, Cambridge.

Topal, T., Akın, M., (2009). Kuzey Anadolu Fay Zonu Üzerinde Yer Alan Erbaa (Tokat) İlçesinin Coğrafi Bilgi Sistemi Tabanlı Mikrobölgelendirmesi. TÜBİTAK ÇAYDAG Proje No: 107Y068.

TS EN ISO 14688-2 (2018) Geotechnical investigation and testing - Identification and classification of soil - Part 2: Principles for a classification

Turkish Earthquake Code, TEC-1975, Ministry of Public Works and Settlement. Specification for Structures to Be Built in Disaster Areas, Government of Republic of Turkey, 1975.

Türkoğlu, N., (2001), "Türkiye'nin Yüzölçümü ve Nüfusunun Deprem Bölgelerine Dağılışı", Ankara Üniversitesi. Türkiye Coğrafyası Araştırma ve Uygulama Merkezi Dergisi, S: 8, s: 133-148, Ankara

Uyanık, O., (2015) Deprem Ağır Hasar Alanlarının Önceden Belirlenmesi ve Şehir Planlaması için Makro ve Mikro Bölgelendirmelerin Önemi. Süleyman Demirel Üniversitesi Fen Bilimleri Enstitüsü Dergisi 19(2), 24-38, 2015.

Yalçınkaya, E., (2010). Zemin Neden Bu Kadar Önemli? Jeofizik Bülteni. Haziran 2010 77-80. ResearchGate.(https://www.researchgate.net/publication/305656493).

Yıldırım, K.; Nişancı ,H., (2023) Antik Çağlardan 10'uncu Yüzyıla Kadar Anadolu'da Depremler. Avrasya Dosyası Dergisi Cilt 14 (Sayı 1): 112-136, İstanbul.

Yılmaz, S., (2020). Aydınlanmacı Öznenin Varoluş Problemi: Kant ve Kleist. Mülkiye Dergisi, 44 (1), 131-164.

URL1http://www.koeri.boun.edu.tr/sismo/bilgi/depremnedir/index.htm#KONU1Erişim: 02.02.2023

URL2 https://www.afad.gov.tr/turkiye-deprem-tehlike-haritasi

URL3 http://www.koeri.boun.edu.tr/sismo/2/deprem-bilgileri/buyuk-depremler/

URL4 https://www.elazig.bel.tr/kent-rehberi/cografi-yapi/217/

URL5 https://www.elazig.bel.tr/kent-rehberi/tarih/216/

URL6 https://tdth.afad.gov.tr/TDTH/detayliRapor.xhtml

T.C.
ELAZIĞ BELEDİYE BAŞKANLIĞI
İmar ve Şehircilik Müdürlüğü

Sayı : E-93342409-622.03-58181

25.09.2023

Konu : TEZ ÇALIŞMASI İÇİN VERİ İZNİ

Sayın RÜVEYDA EMANET YILMAZ

İlgi : 20.09.2023 tarihli ve sayılı yazınız

Yapacağınız tez çalışmasında Elazığ Belediyesi jeolojik jeofizik raporlarında kayıtlı olan sondaj ve jeofizik verilerinin kullanılmasında sakınca bulunmamaktadır.

Bigilerinize rica olunur.

Mustafa PİRİNÇCİ
Belediye Başkan Yardımcısı

Bu belge, güvenli elektronik imza ile imzalanmıştır.
Doğrulama Kodu: ZyG1Lo-x+8vsB-oQBw5Q-eIemK1-wURfZ1e5 Doğrulama Linki: https://www.turkiye.gov.tr/icisleri-belediye-ebys

Cumhuriyet Mah. Malatya Caddesi No:30 - Elazığ
Telefon No: (424)248 47 01 Faks No: (424)248 30 23
e-Posta: elazig@elazig.bel.tr İnternet Adresi: https://www.elazig.bel.tr/
Kep Adresi: elazigbelediyesi@hs01.kep.tr

Bilgi için: Tülay KURTOĞLU
Mühendis
Telefon No:

1