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EFFECTS OF PGA AND SOIL CLASS ON THE DESIGN OF MULTI-STOREY REINFORCED CONCRETE STRUCTURES

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IN

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BY

MEHMET SAİD ERSOY

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Supervisor

Assoc. Prof. Dr. Talha EKMEKYAPAR

by

Mehmet Said ERSOY

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ABSTRACT

EFFECTS OF PGA AND SOIL CLASS ON THE DESIGN OF MULTI-STOREY REINFORCED CONCRETE STRUCTURES

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The majority of the building stock in Turkey is composed of reinforced concrete structures, and due to its location in the Alpine-Himalayan region, earthquake risk remains a vital concern in the country. The high seismic risk in Turkey and the increase in multi-story reinforced concrete buildings make the seismic performance and cost analysis of structures a crucial factor. The seismic behavior of a building is directly related to the interaction between the three interconnected systems of the foundation system, superstructure surrounding the foundation system, and the soil medium. Therefore, to prevent significant loss of life and property during earthquakes, the design of a structure should be tailored to the class of soil. Soil class, soil bearing capacity, and other properties determined by geophysical methods are essential steps in designing a building appropriate for the soil. In this study, to observe the critical effects of soil class and Peak Ground Acceleration (PGA) on the behavior of multi-story reinforced concrete buildings, 12 models of a 12-story reinforced concrete building with the same architectural plan, consisting of 1 basement, 1 commercial, and 10 normal floors, were established for 3 different locations with various PGA values (0.140, 0.28, 0.382) and 4 different soil classes (ZA, ZB, ZC, and ZD) using the IdeCAD package program. As the soil class deteriorated and the PGA rate increased, the building's period values, earthquake-induced moments affecting the structure, relative floor displacements, horizontal loads acting on the floors, and moments generated in the building's foundation increased. In addition to the analyses conducted, the formwork, concrete, and reinforcement quantities of the buildings were also compared.

Key Words: Soil Class, Peak Ground Acceleration, RC Buildings, Earthquake, TBDY-2018, TS500.

ÖZET

ZEMİN SINIFI VE PGA'NIN ÇOK KATLI BETONARME YAPILARA ETKİSİ

ERSOY, Mehmet Said
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Türkiye'de yapı stoğunun büyük kısmı betonarme yapılardan oluşmakta olup, alp-himalaya bölgesinde olduğu için Türkiye'de deprem riski canlılığını korur. Ülkemizde deprem riskinin son derece yüksek olması ve çok katlı betonarme yapıların artması, yapıların deprem performans ve maliyet analizini önemli bir faktör haline getirmiştir. Bir binanın sismik davranışı, temel sistemini çevreleyen üst yapı, temel ve zemin ortamı olan birbirine bağlı üç sistem arasındaki etkileşimle doğrudan ilişkilidir. Bu nedenle depremlerde büyük can ve mal kayıplarının önüne geçmek için zemin tipine en uygun yapı tasarımı geliştirilmelidir. Zemin sınıfı, zemin taşıma kapasitesi ve jeofizik yöntemlerle belirlenen diğer özellikler, zemine uygun bir binanın tasarımında oldukça önemli bir adımdır. Bu çalışmada Betonarme yapıların deprem esnasındaki davranışlarında çok kritik öneme sahip olan zemin türü ve Tepe Yer İvmesi (PGA)'nin çok katlı betonarme binalar üzerindeki etkisini görebilmek adına aynı mimari plana sahip; 1 bodrum, 1 ticari ve 10 normal kattan oluşan toplam 12 katlı çok katlı betonarme bir binanın çeşitli PGA değerlerine (0.140,0.28, 0.382) sahip 3 farklı lokasyon ve 4 farklı zemin türü (ZA, ZB, ZC ve ZD) için toplamda 12 adet modeli kurularak zemin türü ve PGA'nın deprem davranışı üzerindeki kritik etkileri IdeCAD paket programı kullanılarak incelenmiştir. Zemin sınıfı kötüleştikçe ve PGA oranı arttıkça, bina periyot değerleri, yapıyı etkileyen deprem momentleri, göreli kat ötelemeleri, katlara etki eden yatay yükler ve yapının temelinde oluşan momentler artmıştır. Yapılan analizlerin yanı sıra, binaların kalıp, beton ve donatı miktarları da karşılaştırılmıştır.

Anahtar Kelimeler: Yerel Zemin Sınıfı, Tepe Yer İvmesi, Deprem, Betonarme Bina, TS500, TBDY-2018.

"Dedicated to my family"

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LIST OF SYMBOLS

g	Gravitational acceleration [$g = 9.81\ m/s^2$]
Cu	Average Undrained Shear Strength
Vs	Average shear wave velocity
Ns	Average Standard penetration blow Count
Fck	Concrete Characteristic Compressive Strength
Fctk	Concrete Characteristic axial Tensile Strength
Fyk	Characteristic yield strength of longitudinal reinforcement
Fsu	Breaking Strength of Longitudinal reinforcement
Ec	Concrete Modulus of Elasticity
Es	Rebar Modulus of Elasticity
Ɛsu	Rebar elongation at Break
S_S	Short period map spectral acceleration coefficient [dimensionless]
S_1	Map spectral acceleration coefficient for a 1.0 second period [dimensionless]
F_S	Local ground effect coefficient for the short period region
F_1	Local ground effect coefficient for 1.0 second period
S_{DS}	Short period design spectral acceleration coefficient [dimensionless]
S_{D1}	Design spectral acceleration coefficient for a 1.0 second period [dimensionless]
$S_{ae}(T)$	Horizontal elastic design spectral acceleration [g]
T	Natural vibration period [s]
T_A	Horizontal elastic design acceleration spectrum corner period [s]
T_B	Horizontal elastic design acceleration spectrum corner period [s]
T_L	Transition period [s] to the constant displacement region in the horizontal elastic design spectrum
R	Carrier System Behavior Coefficient
D	Strength Excess Coefficient

LIST OFABBREVIATIONS

PGA	Peak Ground Acceleration
PGV	Peak Ground Velocity
BKS	Building Use Class
DTS	Earthquake Design Class
BYS	Building Height Class
I	Building Significance Factor
ANN	Artificial Neural Network
TSE	Turkish Standards Institution
DBS	Design Based Strength
DAR	Evaluation and Design According to Deformation
UU	Uninterrupted Use Performance Level
LD	Limited Damage Performance Level
CD	Controlled Damage Performance Leve
PC	Prevention of Collapse Performance Level
PI	Plasticity Index
ESL	Equivalent Seismic Load
TBDY 2018	Turkey Building Earthquake Regulation
TDY 2007	Turkey Earthquake Regulation
TS 500	Design and Construction Rules of Reinforced Concrete Structures
TDTH	Turkey earthquake hazard map
DD-1	An earthquake with a 2% probability of being exceeded in 50 years (recurrence period of 2475 years) movement level
DD-2	An earthquake with a 10% probability of exceedance in 50 years (recurrence period of 475 years) movement level
DD-3	An earthquake with a 50% probability of being exceeded in 50 years (recurrence period of 72 years) movement level
DD-4	An earthquake location with a probability of exceedance of 68% in 50 years (recurrence period of 43 years) movement level

CHAPTER 1
INTRODUCTION

1.1 General

A large part of the population that has lived and is living in the world has been exposed to earthquakes, albeit low-intensity, throughout their lives. Our country is exposed to hundreds of earthquakes of different magnitudes throughout the year due to its geographical location and young formation. Furthermore, earthquakes are the primary type of natural disaster in our country in terms of loss of life and property [1]. Roughly 60 percent of casualties due to disasters are due to earthquakes. Owing to its geographical location, Turkey is situated on the orogenic belt of Mediterranean-Alpine-Himalayan [2], which is one of the most active earthquake zones. Being an active belt, around twenty percent of the earthquakes worldwide occur on this belt, and it causes a catastrophic earthquake in Turkey approximately once every five years [1].

In Turkey, which is on one of the most active earthquake belts; There are 3 major fault lines, namely the North Anatolian Fault Line, the East Anatolian Fault Line, and the West Anatolian Fault Line. It is known that a large part of the country is under the threat of earthquakes with small-scale fault lines.

It is understood that the number of earthquakes in Turkey (Figure 1.1) is quite high when we look at the annual number of earthquakes published on the official website of AFAD. Also, when we look at the places where these earthquakes occur (Figure 1.2), it is seen that most of these earthquakes are around these fault lines.

If significant security measures and resistance conditions against these earthquakes are not provided; minor, moderate, or serious damage to structures may appear [3].

Knowing that our country is generally an earthquake zone has declared the necessity of taking precautions against material and moral losses caused by earthquakes.

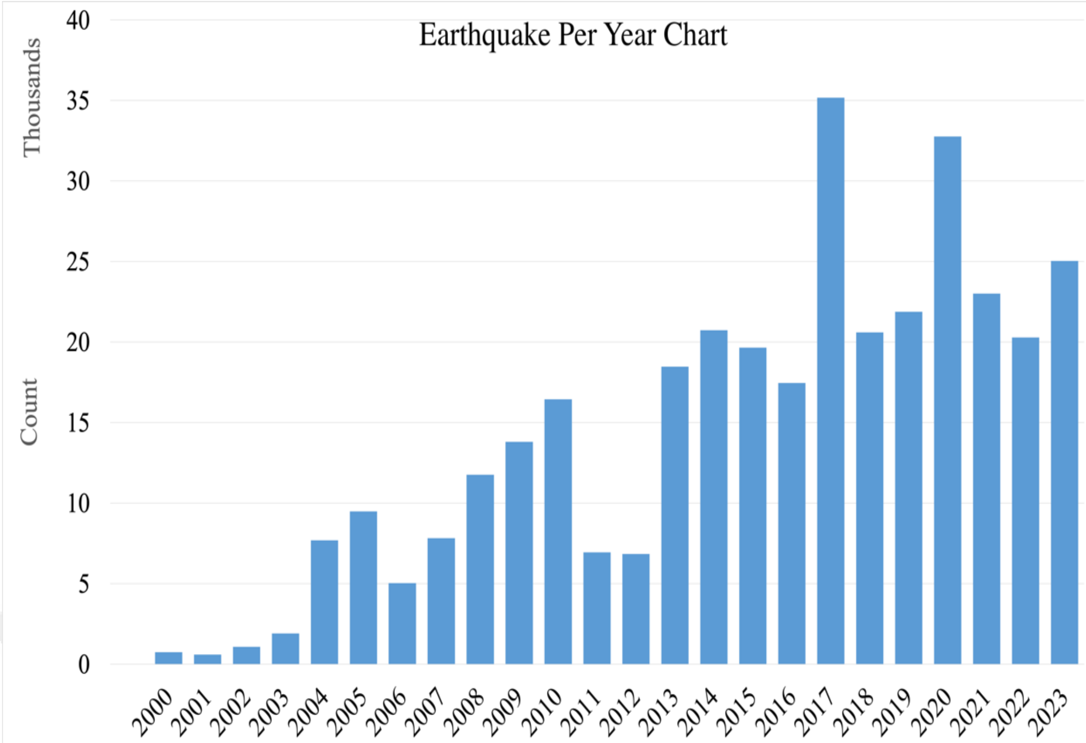


Figure 1.1 Earthquake per year chart (AFAD) [1]

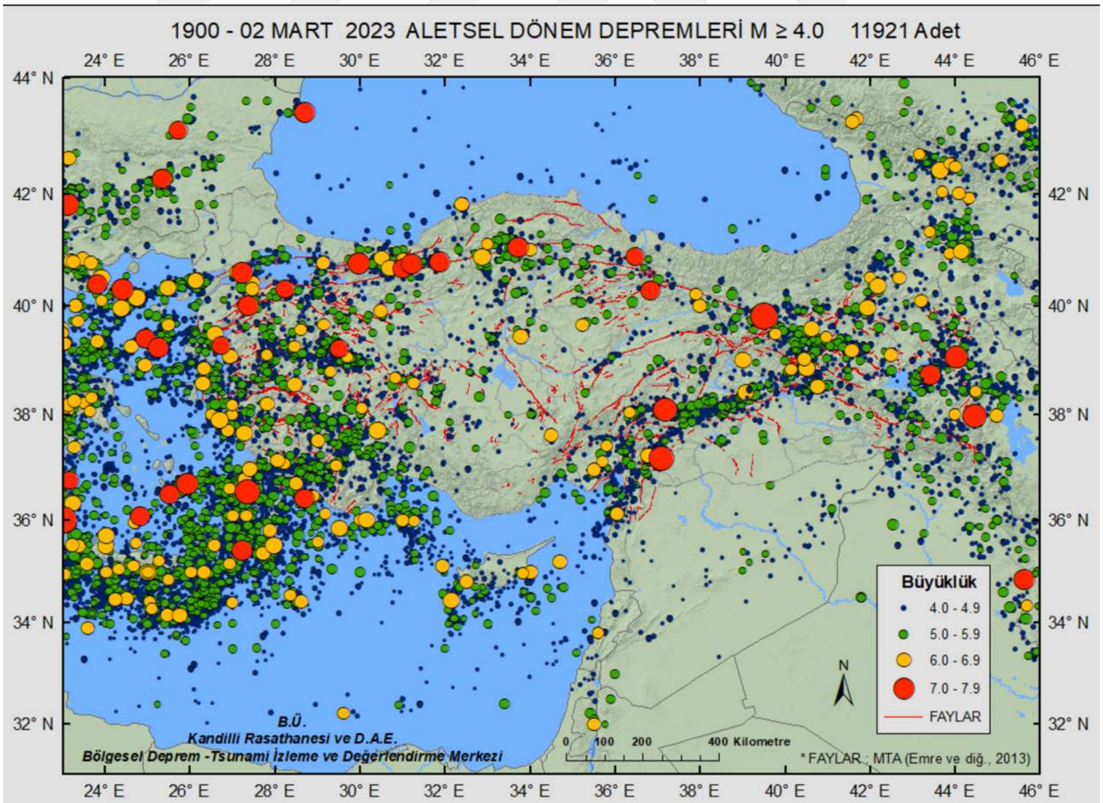


Figure 1.2 Earthquake map between 1990-2023 (RETMG) [4]

The first earthquake code, which was published in 1940 with the name “Building Regulations for Construction in Earthquake Zones”, was revised in 1944, 1949, 1953, 1962, 1968, 1975, 1998, and 2007 and renewed under different names. The Turkish Building Earthquake Regulation-2018 [5], which was published in the Official Gazette on 18.03.2018 and entered force on 01.01.2019, explains more modern approaches and analysis methods for safe building design in detail [5]. There have been many changes to the TBDY 2018 Regulation. One of these changes is the map update used for Turkey Earthquake Risk. The earthquake risk map from zone 1st to zone 5th in the old earthquake map (Figure 1.2) was removed with TBDY 2018. The newly created map (Figure 1.3) is the Earthquake Hazard Map [6]. In addition, earthquake levels were created according to the earthquakes that the buildings to be analyzed will be exposed to. These earthquake levels are DD-1, DD-2, DD-3, and DD-4 levels [5], [7].

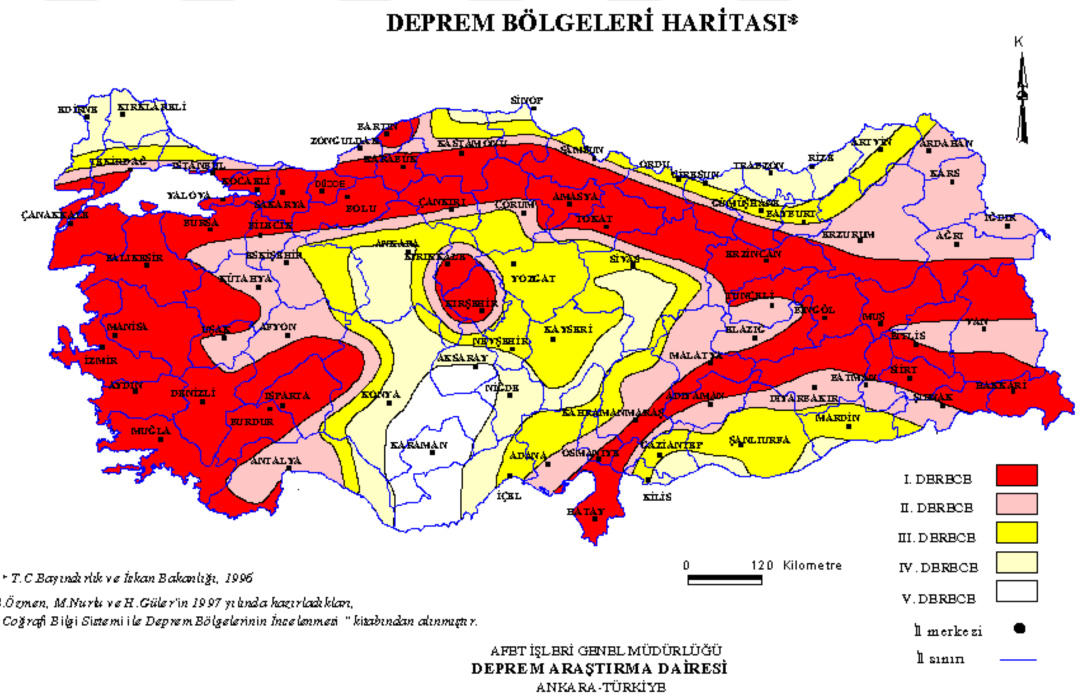


Figure 1.3 Earthquake zones map (AFAD) [8]

With the construction programs developed in conjunction with the advancement of technology, necessary analyzes and evaluations can be made on the structures planned to be built before the earthquakes in question, and information about the behavior of the structure during and after the earthquake can be obtained.

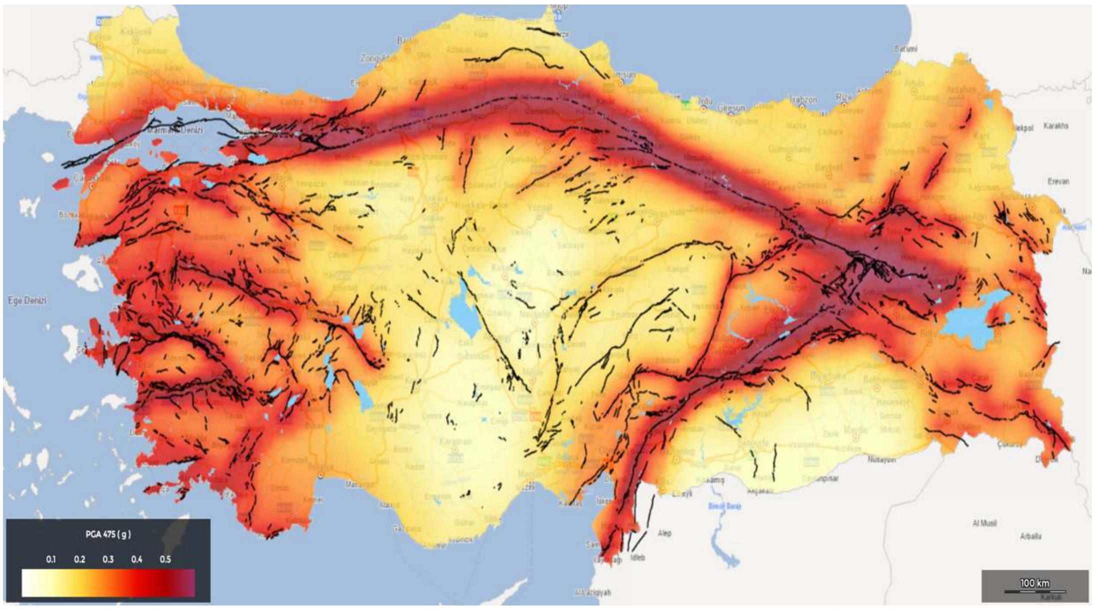


Figure 1.4 Turkey earthquake hazard map (AFAD) [9]

1.2 The Importance of the Thesis Study

The importance of this study is to investigate the factors affecting the design and analysis of multi-storey reinforced concrete buildings. As it is known, Soil parameters have an important place in shaping the design acceleration spectra. This research includes the design and analysis of the multi-storey reinforced concrete plan, which is considered as an example, on different Soil classes by the TBDY-2018 regulation. In addition to the Soil class, the effect of the Peak Ground Acceleration (PGA), which is among the innovations brought by the TBDY-2018 regulation, which entered into force on 01.01.2019, on reinforced concrete buildings was also examined. As a result of this study, the earthquake forces acting on the buildings will be compared and an idea will be gained about the designs that will meet these earthquake forces. Finally, at the end of the whole study, the effect of Soil classes on the building and PGA will be determined and calculated to what extent it changes its costs.

1.3 Objectives of the Thesis Study

The main purpose of the thesis study is to determine the effect of the Soil Classes (ZA, ZB, ZC) and the Peak Ground Acceleration (PGA) on a reinforced concrete building that has 38.2 meters total height, consisting of 1 basement, 1 commercial floor, and 10 normal floors. It aims to contribute to the literature in both theoretical and practical fields through a computer program (IdeCAD V10.94). With this context in mind, the purpose of this thesis study is as follows:

- First, to determine the seismic loads due to varying PGA values on the ground with the same bearing capacity as the reinforced concrete building.
- Second, to determine the cross-sections of the reinforced concrete building to meet the seismic loads to which it is exposed, for Soil Classes with the same PGA value but with varying Soil bearing capacity.
- Finally, to find the aspects of the reinforced concrete building (Relative story displacements, the total equivalent seismic load (base shear), the maximum top displacement, raft foundation sections, etc.) that change under these changing parameters.

1.4 Organization of the Thesis Study

The organization of the thesis study is as follows:

Chapter One Introduction: This chapter presents the research topic and identifies the overall range and specific objectives. The knowledge and aims of the thesis are introduced.

Chapter Two Literature Review: This section concludes the literature review on Soil Class, Peak Ground Acceleration and Response Spektrum. Analysis, three of the key factors discussed in this thesis.

Chapter Three: Method: This chapter explained the analytical modeling of the reinforced concrete system. The method and parameters for the analysis and design of the structures were detailed.

Chapter Four Analysis Results: Results from the static analysis for the reinforced concrete structure with different Soil and Peak Ground Acceleration were given. Discussion of the results of the analysis was described in this chapter.

Chapter Five Conclusions and Recommendations: General conclusions are drawn concerning the general results from all chapters.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

Previous research on the effects of Soil classes and Peak Ground Acceleration rate on the design of reinforced concrete buildings is critically discussed in this section, which also covers numerical and experimental research on seismic codes published regarding the design and analysis method of reinforced concrete structures. The purpose of this literature review; The aim is to gather attention to the absence of knowledge in reinforced concrete structures by citing the latest contributions of research on reinforced concrete buildings.

2.2 Previous Studies Survey

Tarque et al. used probabilistic seismic hazard analysis (PSHA) to estimate the seismic hazard level in Malaysia, including the Sabah region, which has the highest Peak Ground Acceleration (PGA) compared to other states in Malaysia. The study presented a hazard curve for Malaysia using a combination of local faults in the region. Using probabilistic analysis, the study calculated the seismic hazard curve for Malaysia for 10%, 5%, and 2% probability of exceedance (PE) over a 50-year design period, taking into account earthquake records from 1900 to 2021. The PGA values in the bedrock were estimated to be approximately 0.16, 0.21, and 0.28 g for 10%, 5%, and 2% PE, respectively. The study also noted that these values are applicable to Malaysia as a whole [10].

Biva and Huanjun conducted a study to analyze the seismic performance of 18 reinforced concrete moment frame structures designed according to the Chinese and Indian codes. For this purpose, a parametric study was carried out by changing parameters such as building height and Soil clas. Nonlinear time history analysis method was used for four different damage levels (full functionality, functional, repairable, and collapse prevention). The results of the study revealed that structures designed according to the Indian code experienced higher storey drifts compared to those designed according to the Chinese code.

Therefore, it was noted that structures designed according to the Indian seismic code were more vulnerable when subjected to the same earthquake intensity [11].

Akyıldız and Ayhan considered the parameters of the ground in five different regions in the center of Siirt in order to compare the Soil parameters and earthquake data according to the TDY 2007 and TBDY 2018 earthquake codes. In his work, he made two different models, each with five floors and same foundation system. Although he did not receive any warning about the sections of the building whose static analysis was made according to the TDY 2007 earthquake regulation, he received warnings about the section deficiencies in the building that were statically analyzed according to the TBDY 2018 earthquake regulation. As a result, he found that the cost of a structure designed and analyzed according to TBDY 2018 increased by an average of 1,60% compared to TDY 2007. he stated that the resulting cost increase means that more stringent measures have been taken on the safety of human life and property in the 2018 regulation, but as the safety factor comes to the fore, it will have an impact on the cost of the building [12].

Cansız in his study, wanted to compare the equivalent horizontal earthquake load calculations to the change in earthquake codes used in Turkey. He used the building, which was designed as a hotel and comprises three basement floors, a ground floor, and five normal floors, as an example. When Cansız compared the findings of his study; It was found that the last four earthquake codes calculate the equivalent horizontal earthquake load in decreasing form, but the last regulations are more reliable due to the increase in the effect of the internal forces based on the design [13].

Pandu and Priyosulistyo conducted a study at the six-story structural laboratory of the Department of Civil and Environmental Engineering at UGM to verify whether they could predict the Peak Ground Acceleration of a building in resonance with Indonesia's seismic code SNI:1726-2012 using the theory proposed by Nakamura. They placed accelerometers in the North-South and East-West directions alternately at the bottom of columns near the center of gravity of the building on each floor. Additionally, they performed a numerical calculation using the SAP 2000 program to compare their findings. The results of their study showed that such a prediction was 533% higher than field measurements. Thus, they concluded that if resonance does not occur during an earthquake, the building may be subjected to much higher ground accelerations [14].

Raj and Kumar conducted a study on the performance evaluation of scrap tire bumpers (STRP) made from used car tires as seismic dampers. The study used a Fast Nonlinear Analysis (Nonlinear Modal Time History Analysis) approach and applied it to building models with plan irregularity and floor irregularity, as well as six different building models without irregularities. Six different real-time historical records selected based on Peak Ground Accelerations (PGA) were examined for convergence using SeismoMatch software. The dynamic parameters of the buildings were determined and discussed, including base shear, acceleration, floor displacement, floor drift, floor drift ratio, and hysteresis loops. The results of the analysis showed that in buildings with plan irregularities, the reduction of base shear is more significant than in normal and vertically irregular buildings. In vertically irregular buildings, floor displacement and drift responses are more important than in plan irregular and regular buildings. Therefore, it was stated that the seismic responses of buildings are primarily influenced by structural elements and the intensity of seismic events/PGA, regardless of the irregularity profile [15].

Miari and Jankowski conducted the effect of Soil clas on the response of colliding structures exposed to earthquakes was experimentally investigated. The study examined three different collision scenarios, as well as non-collision scenarios with different seismic gaps taken into account. In the first stage of the study, the effect of two colliding structures was analyzed in several scenarios, compared to non-collision scenarios. Subsequently, the effect of seismic gaps was examined to determine their impact on the response of colliding structures. Finally, the effect of Soil class on the response of structures exposed to interaction was investigated. In this context, five different Soil classes defined in the ASCE 7-10 code (hard rock, rock, very dense Soil and soft rock, hard Soil and soft clay Soil) were considered. According to the results of the study, it was observed that the intensity of collision increased as the Soil class deteriorated. These results emphasize the importance of Soil class as a significant factor in improving the seismic performance of structures. The findings of the study provide a significant contribution to the measures to be taken to reduce earthquake damage in the field of structural engineering [16].

Banerjee et al. stated that both static and dynamic analysis methods are used in earthquake analyses. While static methods are suitable for regular structures, they are insufficient for irregular structures. Therefore, the use of dynamic methods is necessary. Banerje and his colleagues emphasized that the Response Spectrum method is a relatively simple method compared to other dynamic methods. They stated that the Response Spectrum method helps to estimate displacements and element forces in structural systems. Therefore, the use of dynamic methods in earthquake analyses is crucial for ensuring the safety of structures, and the Response Spectrum method stands out as a simple but effective option among these methods [17].

Akyıldız et al. in their studies, they made calculations for each Soil class (ZA, ZB, ZC, ZD, and ZE) by choosing the center of Bitlis in order to investigate the effect of local Soil conditions on earthquake section effects. These five different Soil classes made evaluations by considering four different earthquake ground motion levels (DD-1, DD-2, DD-3, and DD-4). They used the 2-storey with 2-opening reinforced concrete plane frame model in their work. They determined concrete class C30/37, steel B420C, storey heights as 3.00 meters, and span lengths as 4.00 meters on all floors. As a result of the analyzes made, they observed that the class of the ground on which the structures are built, the earthquake forces that will come to the structure in case of an earthquake, and the cross-sectional effects of the structure with the effect of these forces change to a large extent [3].

Firar and Günaydın using the Sap2000 (V20) structural analysis program and IdeCAD (V10) package programs, which have become more widespread with the developing technology and are frequently used by civil engineers, are the modal analysis of a four-storey reinforced concrete framed structure at the DD-2 earthquake level, mass participation. Ratios, the total weight of the building, irregularity checks, and relative story displacements checks. As a result of their analysis, they observed that the center of gravity of the floors was similar in both programs, but the structure weight of the model analyzed with Sap2000 was higher. Due to the different weights of the buildings, different values were observed in the dominant period (T) values of the building. As a result, the earthquake force values acting on the structure were higher in the SAP2000 program than in the IdeCAD package program. One of the most important reasons for this is that the floor weights are too high in the SAP2000 program and the period values are different [7].

Özmen and Sayın using the sap2000 structural analysis program, compared the equivalent earthquake loads of a multi-storey reinforced concrete building according to TDY 2007 and TBDY 2018 regulations. It is understood that the amount of increase in the base shear force and structure period values is higher in TBDY 2018 than TDY 2007, and thus, it is desired to increase the building safety more with TBDY 2018 [18].

Özşahin in his study, as a result of the horizontal design spectra according to the earthquake regulations of TDY 2007 and TBDY 2018 in Edirne province; It has been determined that the highest ground acceleration (PGA) values in the Edirne center and all of its districts have increased compared to TDY 2007 compared to TDBY 2018. He suggested that the greatest increase in these increasing PGA values was in the 4th-degree earthquake region (the region with less seismicity) with TDY 2007 [19].

Başaran and Hiçyılmaz used 5-storey and 10-storey reinforced concrete frame models in their studies in which they examined the effects of earthquake ground motion levels and Soil class changes on reinforced concrete frames. As a result of their analysis; They stated that for DD-1 earthquake ground motion, there was an increase in the base shear forces from the ZA Soil class to the ZE Soil class, but when the DD-1 earthquake ground motion level was taken as a reference, there was a decrease in the base shear forces as the DD-4 earthquake ground motion went [20].

Puteri et al. investigated an area of 500 km in the center of Bengkulu province to obtain the Peak Ground Acceleration. They examined seismic activity along the Sumatra fault and found that it could be divided into three different depth classifications (below 93 km, 186 km, and 310 km). They observed that most of this activity occurred below 93 km and therefore many earthquakes occurred as shallow earthquakes. Analyses conducted using the PSHA method showed that the Probabilistic Peak Ground Acceleration (PGA) value exceeding a 10% probability in 50 years in the bedrock of Bengkulu province ranged from 0.24 gal to 0.86 gal [21].

Sucuoğlu examined TBDY 2018 in terms of scope and compared it with the previous earthquake code. He stated that the most important developments regarding the regulation are the earthquake design of high-rise buildings, earthquake-insulated buildings, and pile foundations with the definition of site-specific earthquake hazard [22].

Bayrak used the data from 128 earthquakes in his study, in which he estimated the largest ground acceleration, limited to the eastern provinces of Turkey. With the findings of his study; He suggested that reasonably plausible results can be obtained in modeling earthquakes occurring in a complex environment [23].

Thant and Kyaw conducted a study on the effects of Response Spectrum Analysis (RSA) and Construction Sequence Analysis (CSA) methods on setback steel structures. They used an 11-story setback steel structure model that was 78 feet long and 66 feet wide located in Mandalay, which is not in a destructive zone but exposed to 80 mph wind speed. The analysis results were evaluated based on criteria such as story displacement, maximum axial force, maximum shear force, and maximum bending moment of structural frame elements. The maximum story displacement obtained by using the CSA method was found to be 56% higher compared to RSA. Similarly, the maximum axial force obtained using CSA was 48% higher than RSA. Moreover, the maximum shear force and bending moment obtained using the CSA method were higher than the results obtained by RSA [24].

Khy et al. propose a modified response spectrum analysis (MRSA) method to accurately calculate design shear forces in high-rise reinforced concrete shear wall buildings subjected to earthquake loads in Bangkok. The authors found that reducing elastic forces from all modes using the RSA procedure with a single response modification factor (R) was the main reason for incorrect prediction of design force demands. While the RSA procedure provides good predictions for floor displacements and inter-story drifts, it is insufficient for accurate prediction of design forces. The authors found that the MRSAHE method provides good predictions for shear forces in 15- and 20-story buildings and conservative predictions for 31- and 39-story buildings. On the other hand, the MRSAHI method provides good predictions for all cases, but requires a nonlinear inelastic structural model. In summary, the MRSA method proposed by Khy and colleagues addresses the inadequacy of the RSA procedure for accurate calculation of design shear forces in high-rise reinforced concrete shear wall buildings. While the MRSAHE method provides more consistent predictions in some cases, the MRSAHI method offers a more general solution [25].

Elçi and Göker conducted an experimental and theoretical study to evaluate and compare the earthquake performance of reinforced concrete columns. For this purpose, they prepared four-column samples with the same cross-sections but different reinforcement numbers and reinforcement diameters. They set up an experimental setup that could give loads on the horizontal and vertical axis and measure the loads, and they recorded the displacement movements of the columns under loads with data collection devices. Elci and Goker compared the data they obtained according to the TDY 2007 and the TBDY 2018 regulations. Although the limit values obtained in both regulations are close to each other, in general, TBDY 2018 gives deformation limits that are on the safer side compared to TDY 2007 (TDY 2007, TBDY 2018). As a result, they observed that the TBDY 2018 regulation proposes safer and more ductile solutions [26].

Arslan et al. investigated alternative foundation solutions because of the economic and security principles and the non-economic foundation solutions because of increasing security concerns. In their study, they examined the basic projects of nine pre-built buildings in the cities of Karabük, Safranbolu, Kastamonu, and Çerkezköy. They created alternative projects to the projects they examined and analyzed them by the TBDY-2018 regulation using the IdeCAD package program. They found no alternative foundation to the one used in only one of the nine reinforced concrete buildings they examined. In other projects analyzed, they observed that a continuous foundation would be appropriate and safe enough instead of a raft foundation. They stated that if these projects are solved with an alternative foundation system, approximately 12% acquisition is achieved in terms of construction costs [27].

Öztürk aimed to compare the earthquake hazard maps of 1996 and 2018 based on the Central Anatolia region. In this context, he compared the horizontal acceleration spectra and base shear forces by considering two different Soil classes in Kırşehir, Eskişehir, Kayseri and Konya regions, which are in different earthquake zones on the 1996 map. In this context, he compared the horizontal acceleration spectra and base shear forces by considering two different Soil classes in Kırşehir, Eskişehir, Kayseri, and Konya regions, which are in different earthquake zones on the 1996 map. As a result of his work, he observed that the ground acceleration was reduced in Kırşehir and its surroundings, and the ground acceleration was increased in Konya. When he examined the design spectra, he concluded that TDTH-2018 gave smaller accelerations for the ZB Soil class in Konya, Kayseri, and Eskişehir compared to the 1996 map. In addition, it was concluded that the earthquake hazard map greatly increased the spectral accelerations in weak-strength Soils when the construction period was less than 1 second [28].

Kılıçer and Özgan in their study on the structure-Soil interaction in the design of reinforced concrete structures under the influence of earthquake loads, solved the 12-storey reinforced concrete structure under the influence of the 17 August 1999 Kocaeli earthquake with the Sap2000 structural analysis program, taking into account the ground. As a result of their study, they observed that the difference between the displacements obtained for different Soil models grows as the maximum acceleration value increases. They also stated that the ground-structure interaction is not only an element that affects the foundation design but also has important effects on the superstructure [29].

Keskin and Bozdoğan state that the earthquake hazard is handled in a non-detailed way according to the TDY 2007 regulation, but fortunately, the ground effect affects the calculations more realistically with the seismic hazard map concept that came into force with the TBDY 2018 earthquake regulation [30].

Bakhski and Asadi In their study, conducted probabilistic evaluations of seismic design parameters in reinforced concrete frame buildings, analyzing a total of eight buildings with different heights and spans. One of the objectives of the analysis was to examine the effect of uncertainty in the Peak Ground Acceleration (PGA) parameter. The results showed that the uncertainty in PGA generally increased the probability of damage in buildings. However, in cases where there was a high error percentage at high hazard levels, the probability of damage actually decreased. This was attributed to the high variability levels in these hazard levels [31].

Chandak performed dynamic analysis of three different floor plans of buildings, which are symmetric (SB), monosymmetric (MB), and asymmetric (UB) with torsional irregularity, using the Response Spectrum analysis method in the Sap2000 program to examine the differences created by the use of different earthquake codes. The Indian Standard Code, Uniform Building Code, and Euro Code 8 were considered for comparison in the analysis. As a result of Chandak's analyses, it was determined that the base shear values obtained using the IS code were higher than the other codes for similar Soil class in all three buildings. Additionally, it was observed that while the IS code provided maximum displacement values for the buildings, the UBC provided minimum displacement values [32].

Yuen and Mu in their study, analyzed 266 strong motion records obtained from the China Earthquake Data Center for predicting Peak Ground Acceleration. They created and examined 32 linear and 16 nonlinear prediction model classes. The results of the study indicated that nonlinear model classes were not suitable for the work and required significantly more intensive computation [33].

Vipin et al. aimed to evaluate earthquake risk in Southern India using the Probabilistic Seismic Hazard Analysis (PSHA) method. In this study, earthquake data obtained from different sources were organized to extract dependent events, and then 598 earthquakes with a moment magnitude of 4 or greater were selected from the study area. The seismotectonic map of the study area was prepared by taking into account the faults, lines, and shear zones associated with earthquakes with a magnitude of 4 or greater. To evaluate earthquake risk, the study area was divided into grids of size 0.1° x 0.1°, and the risk parameters at the center of each grid were calculated. The peak horizontal acceleration (PHA) and spectral acceleration (SA) values for one second on rock and Soil, corresponding to a 10% and 2% probability of exceedance in 50 years, were calculated for all grid points. In addition, the Peak Ground Acceleration (PGA) at the surface level was calculated for four different site classes for the entire Southern India [34].

As a result, it was noted that when the site class at any location in the study area is known, PGA values at the ground level can be obtained based on the simplified method adopted in this study.

Güllü et al. aimed to apply the artificial neural network (ANN) to the estimation of the maximum ground acceleration (PGA) in their study. They stated that the correlation coefficient between the accelerations estimated using the neural network and the accelerations measured was 92% in the training phase and 64% in the testing phase [35].

Ambraseys conducted an important study on estimating Peak Ground Acceleration in the European region. The study examined 219 shallow earthquake records at distances ranging from 1 km to 310 km, with earthquake magnitudes ranging from Ms 4.0 to 7.3. The equation used in the study was created by keeping the source distance, depth, and magnitude parameters constant while explaining the relationship between earthquake parameters and Peak Ground Acceleration estimation using various predictive variables. However, the simple equation used in Ambraseys' study did not achieve satisfactory results in terms of the predictability of Peak Ground Acceleration. Therefore, it was stated that more comprehensive and sophisticated models need to be used to estimate Peak Ground Acceleration. Ambraseys' study was an important step in estimating Peak Ground Acceleration for earthquakes in the European region. However, further research in this field and the use of more advanced models will help to estimate Peak Ground Acceleration more accurately and reliably[36].

CHAPTER 3
METHOD

3.1 General

This thesis focuses on the structural analysis of a reinforced concrete building with a width of 22.1 meters, a length of 25.4 meters, and a total height of 38.2 meters. The building consists of one basement level, one commercial floor, and ten normal floors, and it was analyzed considering four different local Soil classes and three different PGA values. The analysis was conducted using the IdeCAD program developed in accordance with the TBDY 2018 and TS500 standards. The IdeCAD program creates 3D models of the building and performs all necessary calculations to ensure structural performance and safety. The results of this study were evaluated based on the results obtained using the IdeCAD program.

Based on the results, vital topics crucial in determining seismic performance were subjected to a comprehensive comparison. This comparison focused on important factors such as earthquake period values, base shear forces, relative floor displacements, earthquake loads, lateral loads affecting floors, and seismic moments. In addition, the structural changes caused by earthquake forces were also examined in detail in cross-sections.

Furthermore, the amounts of reinforcement, formwork, and concrete were calculated for each model, and the cost of the structure was calculated using unit prices determined by the Ministry of Environment, Urbanization, and Climate. This enabled the evaluation of the relationship between structural analysis results and costs, aiming to design a more economical and sustainable structure.

3.2 Regulations

3.2.1 Turkey Building Earthquake Regulation

In order to create and fulfill all these processes, it is important for all humanity to establish a commission consisting of experts from relevant and necessary public institutions and organizations, together with expert researchers on the subject, and to ensure that these studies continue continuously. The studies carried out in order to eliminate the deficiencies in the regulations and methods continue at full speed. In order to improve existing buildings for buildings or structures with low earthquake resistance in order to be prepared for any earthquake that may occur; The latest developments and methods regarding earthquakes, although the General Principles for Earthquake Ground Motion and Design are available in the previously published regulation in our country, they have been revised in detail and 2018 Turkey Building Earthquake Regulation has been established [37].

The name of the new earthquake regulation titled Principles for the Design of Buildings Under the Impact of Earthquakes has been abbreviated as Turkey Building Earthquake Regulation. It was published in the Official Gazette on March 18, 2018, together with the Earthquake Hazard Map of Turkey. In parallel with the publication of the new earthquake regulation, the publication of the new Turkey Earthquake Hazard Map on the same date is a very important development. With this modern map, the concept of seismic zone has been removed, and the earthquake hazard and related engineering parameters, which are determined more safely by advanced methods for four earthquake ground motion levels, are practically defined numerically for each location. The main features and innovations of the New Turkish Building Regulation can be summarized under three headings. Improvement; The Regulation on Buildings to be Constructed in Earthquake Zones, without making any principal changes in the usual calculation and design approaches, the developments and innovations in this field were reflected in the new regulation, deficiencies and implementation problems were tried to be eliminated. One of the most important improvements made in the new regulation is the detailed rules for the design of the foundation Soil and foundations under the effect of earthquakes. Development; The performance evaluation and design approach, which was limited in the old regulations, is explained in detail in order to be applied both to the design of new buildings and to the evaluation and retrofit design of existing buildings. In this context, provisions regarding the application of modern calculation and design approaches in important buildings and high-rise buildings have been introduced. New technologies; Special rules have been developed for the calculation and design of new types of carrier systems and elements, and new regulation sections have been created. In this context, in addition to the rules for high-rise buildings, insulated buildings and light steel buildings, innovations such as allowing the use of buckling-prevented steel braces and defining detailed design rules for reinforced masonry walls are included.

3.2.2 TS 500

The Turkish Standards Institution (TSE), established in Turkey in 1978, began work on preparing TS 500. As part of this work, standard test methods for building materials were determined, and standards were created regarding the performance, durability, and quality of materials.

TS 500 was first published in 1983. Since its publication, the standards set under TS 500 have been an important tool for improving the quality of materials used in the construction sector in Turkey. TS 500 is also an important reference source for determining the standards of materials used in the construction of earthquake-resistant structures in Turkey, given that it is located in an earthquake zone. The purpose of this standard is to determine the quality, performance, and durability of building materials and to test their suitability. TS 500 determines the properties of various building materials and is followed by their manufacturers and users. The building materials standards set under TS 500 include concrete structural elements, steel structural elements, wooden structural elements, bricks, blocks, roofing materials, and various other building materials.

Some of the standards set under TS 500 for concrete structural elements include:

- Concrete strength: TS 500 determines the minimum strength values of concrete, which are important for the durability and safety of concrete structural elements (TS 500 table 3.2).
- Steel reinforcement: The properties and quality of steel reinforcement used in concrete structural elements are determined under TS 500 (TS 500 table 3.1).
- Dimensions and shapes of concrete structural elements: TS 500 determines the minimum dimensions and shapes of concrete structural elements, which are important for their durability and safety.

3.3 Evaluation of PGA and Soil Class

3.3.1 Effects of the Peak Ground Acceleration on Reinforced Concrete Structures

Peak Ground Acceleration (PGA) is an important factor when it comes to understanding the effects of an earthquake on a structure. The value of PGA can vary significantly and may range from very low values, such as less than 0.1g, to extremely high levels, such as greater than 2.0g (the force of gravity). PGA is commonly measured in units of gravitational acceleration (g) or in cm/s^2.

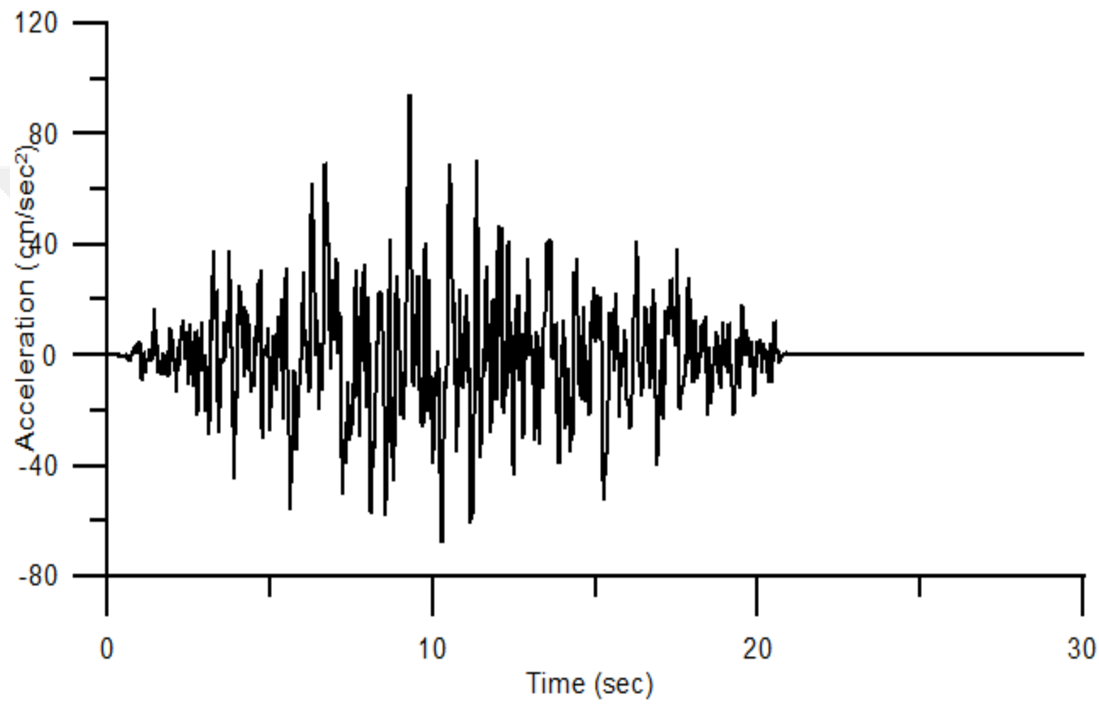


Figure 3.1 Representative PGA graph

Generally speaking, the higher the PGA, the more intense the ground shaking and the greater the potential for damage. That's why it's important for engineers to consider PGA when designing structures to resist earthquakes. Factors such as Soil class, building height, and structural design all play a role in determining how much of an effect an earthquake will have on a building. This is why a comprehensive structural analysis should be conducted to determine the appropriate design parameters for the specific site. PGA is especially important in areas that experience frequent earthquakes, as buildings must be able to withstand the shaking of the earth without collapsing.

By taking into account PGA measurements, engineers can ensure that buildings and structures are built with the highest possible level of earthquake resistance. Therefore, engineers never neglect PGA when designing earthquake resistant structures.

3.3.2 Effects of the Soil Class on Reinforced Concrete Structures

The Soil class is an indication of the class of Soil at the site, which is used to estimate the seismic response of the structure. Soil class plays an important role in how well a building can withstand earthquakes. Different classes of Soil can have vastly different effects on the seismic stability of a structure. Each Soil class has different levels of strength and stiffness, which can affect the amount of resistance it provides during an earthquake. Soil classes are divided into six categories. They are ZA, ZB, ZC, ZD, ZE and ZF, with ZA being the most resistant to seismic motion and ZF being the least resistant (Table 3.1). Soil class is important for seismic analysis because it helps to determine the Soil-structure interaction. This interaction is then used to calculate the seismic design force, which is then used to design the structure. Soil class also helps to identify the seismic hazard level of the site and can be used to estimate the potential seismic risk that the structure may be exposed to. When building in earthquake-prone areas, it is important to take Soil class into account to maximize resistance. In some cases, it may even be necessary to reinforce the Soil with concrete or other materials to increase the structure's resistance.

Reinforced concrete buildings are most suitable for earthquake-prone areas as they are designed to dissipate the forces of ground motion, however buildings constructed on hard Soil may experience minor displacement, while buildings on soft Soil may experience significant lateral displacement. that is why by analyzing the class of Soil and incorporating suitable measures into the reinforced concrete building design, it is possible to increase its earthquake resistance significantly.

The Soil parameter values mentioned in Table 3.1 will be determined for the uppermost 30 m thick sections of the Soil profile when the main heading of the Soil profile is examined downwards starting from the lower level.

Table 3.1 Local soil classes (TBDY) [5]

Local Soil Class	Soil Type	Average in the top 30 meters		
		$(V_s)_{30}$ [m/s]	$(N_{60})30$ [beat /30 cm]	$(C_u)30$ [kPa]
ZA	Solid, hard rocks	>1500	-	-
ZB	Less weathered, moderately strong rocks	760-1500	-	-
ZC	Very tight layers of sand, gravel and hard clay or weathered, very cracked weak rocks	360-760	>50	>250
ZD	Medium Firm-tight layers of sand, gravel or very solid clay	180-360	15-50	70-250
ZE	Profiles containing loose sand, gravel or soft-solid clay layers or a total thickness of soft clay layers (Cu < 25 kPa) of more than 3 meters in total meeting the conditions of PI > 20 and w > 40%	<180	<15	<70
ZF	Grounds that require site-specific research and evaluation: 1) Soils that have the risk of collapse and potential collapse under the influence of earthquakes (liquefiable Soils, highly sensitive clays, collapsible weak cemented Soils, etc.), 2) Clays with a total thickness of more than 3 meters of peat and/or high organic content, 3) High plasticity (PI > 50) clays with a total thickness of more than 8 meters, 4) Very thick (> 35 m) soft or medium solid clays.			

In Soil profiles containing rock and Soil layers with significantly different shapes, the layers in the upper 30 meters will be divided into sufficient lower layers and arranged in a way that i = 1 at the top and i = N at the bottom. The average calculated shear wave velocity (Vs)30, the average standard penetration impact number (N60) 30 and the average undrained shear strength (Cu) 30 in this upper 30 meters will be found by the following equation (2.1) [5].

$$(V_S)_{30} = \frac{30}{\sum_{i=1}^{N}\left(\frac{h_i}{V_{s,i}}\right)} \quad ; \; (N_{60})_{30} = \frac{30}{\sum_{i=1}^{N}\left(\frac{h_i}{N_{60,i}}\right)} \quad ; \; (C_u)_{30} = \frac{30}{\sum_{i=1}^{N}\left(\frac{h_i}{C_{u,i}}\right)} \qquad (3.1)$$

Here, the thickness (m) of the substrates with the number hi (i), Vs,i, N60,i and Cu,i, respectively, the shear wave velocity of the same substrate (m/s), the standard penetration test impact number (pulse/ 30 cm) and undrained shear strength (kPa) [5].

3.4 Bearing Capacity of Soil

A structural system can be broadly divided into two parts. The upper section is defined as the superstructure. The intermediate zone between the ground and the superstructure is also defined by the name of the foundation. The superstructure, foundation and ground combinations together form the system of a building. The foundation is the intermediary part of the structure that interacts directly with the ground and transfers the superstructure loads to the ground. In other words, the foundation is a system that transmits the loads coming from the structure and the total load distribution coming from the structure together with the building loads, by transforming the ground into a condition that can carry these loads. With this feature, it is affected by the basic structure and the ground. In other words, it can be said that the design phase of the foundations is a problem related to the structure-Soil interaction. They are divided into two subgroups within the foundations. These are deep (caisson, pile, foot) and shallow (single, continuous and raft foundation) foundations. The foundations to be built are highly dependent on the conditions of the ground. Some Soils on which foundations will be built are soft and some are hard. Hard Soils can soften when water is absorbed, some Soils swell and can lift shallow foundations, some Soils collapse and the foundation sinks into the ground. A well-designed foundation is a foundation design that is made in such a way as to fulfill its expected duty in all bad conditions and in all changes that occur. Misapplications or mistakes made during the planning phase of the foundation system of a building, which has an important task, may come to light of course. A successful design and implementation will only be achieved if a building and its foundation can successfully survive despite various disasters [38].

3.5 Earthquake-Ground Relationship

During the occurrence of earthquakes, waves of different sizes emanating from the source of the earthquake are dispersed in the ground at different speeds. When these waves reach the surface, they can create vibrations that last for seconds or minutes. The duration and intensities of these vibrations; It varies depending on the magnitude of the earthquake, the distance from the source where it occurred, the physical characteristics of the place where the earthquake waves travel (through which they pass) and the characteristics of the layers of the Soil through which the earthquake waves pass.

When these waves, which move from the bedrock to the earth's surface, reach the Soil layers, they are filtered in these layers. Soil layers act as a filter on earthquake waves and cause the general characteristics of earthquake waves to change. While the waves can sometimes be damped in this process, they grow in waves of some different frequency. All the effects in which these changes occur are called the ground effect, and this effect is also called the ground amplification since the amplitudes of the waves have progressed in the direction of increasing [39].

After earthquakes occur, new movements such as softening, settlement or liquefaction may occur in the Soils with their effects. The most important of these movements is liquefaction. With the effect of liquefaction, new settlements and new softening may occur. If a sudden seismic force (i.e., earthquake shock) is applied to the spaces between the sand particles in the sand layers close to the ground, the balances between the sand particles are disturbed and the sand and water begin to move towards the ground and the upper surface, which causes liquefaction in the ground. With liquefaction, the sand moves with the water, causing the ground to behave like a liquid. Structures on liquefied Soils, on the other hand, are buried in the ground and exposed to different settlements, and for this reason, different deformations such as rotation and lateral tilting occur in the structures. For this reason, it is very important to determine the Soil stratification and all the index and strength properties of Soils in detail by drilling before the construction phase of the structure in the construction areas where sandy silty Soil layers are present. In addition, the liquefaction of Soil layers should be examined and evaluated in detail together with dynamic analysis [40].

3.6 Introduction of the Computer Program to be Used

IdeCAD is a popular computer-aided design (CAD) software primarily used for architectural and engineering design. It is developed by Idestek Group, a technology company based in Turkey.

IdeCAD offers different methods for analyzing the earthquake resistance of structures. One of these methods is the Equivalent Seismic Load (ESL) method. The ESL method is used to determine the earthquake load that will affect the structure and is based on the linear elastic method as the calculation method. The Response Spectrum method, on the other hand, is used to study the behavior of structures under earthquake loads. This method is used to better understand the dynamic behavior of structures during earthquakes. The Response Spectrum method expresses the earthquake load as a spectrum graph and is used to calculate the areas under this spectrum graph for structures.

Therefore, while the earthquake load calculated by the ESL method is considered as a fixed load that affects the structure, the earthquake load calculated by the Response Spectrum method takes into account the dynamic effects that will affect the structure. Both methods can be used for earthquake resistance analysis of structures, but the decision on which method to use depends on the requirements of the structure and the project.

In this study, the Response Spectrum method was used to analyze the earthquake resistance of the structure. This method was chosen in order to better understand the dynamic behavior of the structure during earthquakes and to take into account the dynamic effects that would affect the structure. By using the Response Spectrum method, the areas under the spectrum graph were calculated to determine the structure's earthquake resistance.

3.7 Introduction of the analysis method to be used (Response Spektrum)

The Response Spectrum method is a widely used analysis method in earthquake engineering. It is used to determine the dynamic response of a structure under seismic loads. In this method, the ground acceleration time history is converted into a spectrum, which is a plot of the maximum response of a system to a range of natural frequencies. The spectrum is then multiplied by the structural response acceleration, velocity, or displacement to determine the maximum response of the structure at each frequency.

The Response Spectrum method takes into account the different frequencies of vibration that can occur in a structure during an earthquake. The analysis provides information on the maximum displacements, velocities, and accelerations that the structure will experience, as well as the time duration of the shaking.

The Response Spectrum method is particularly useful for irregular structures, such as buildings with different floor heights or buildings with asymmetric configurations, as well as for structures with non-linear behavior. It is also useful for determining the design forces for different parts of a structure, such as columns and beams, and for estimating the deformation demand for the structure.

3.8 Description of Building Model

A building model with a uniform architecture, which is the subject of the study and one of its constraints, has been created. After the static drawing of this sample architectural project was made, it was used repeatedly for each analysis model. While designing the statics of the building, attention was paid to ensure that only the Soil class and PGA were the parameters that will affect the values to be obtained as a result of the analysis. Moreover, in addition to the effects of earthquake loads on the building, in order to prevent additional moments arising from eccentricity; The architectural and static designs of the buildings are designed to be symmetrical, and the center of mass and stiffness centers are designed to coincide with the middle of the building model.

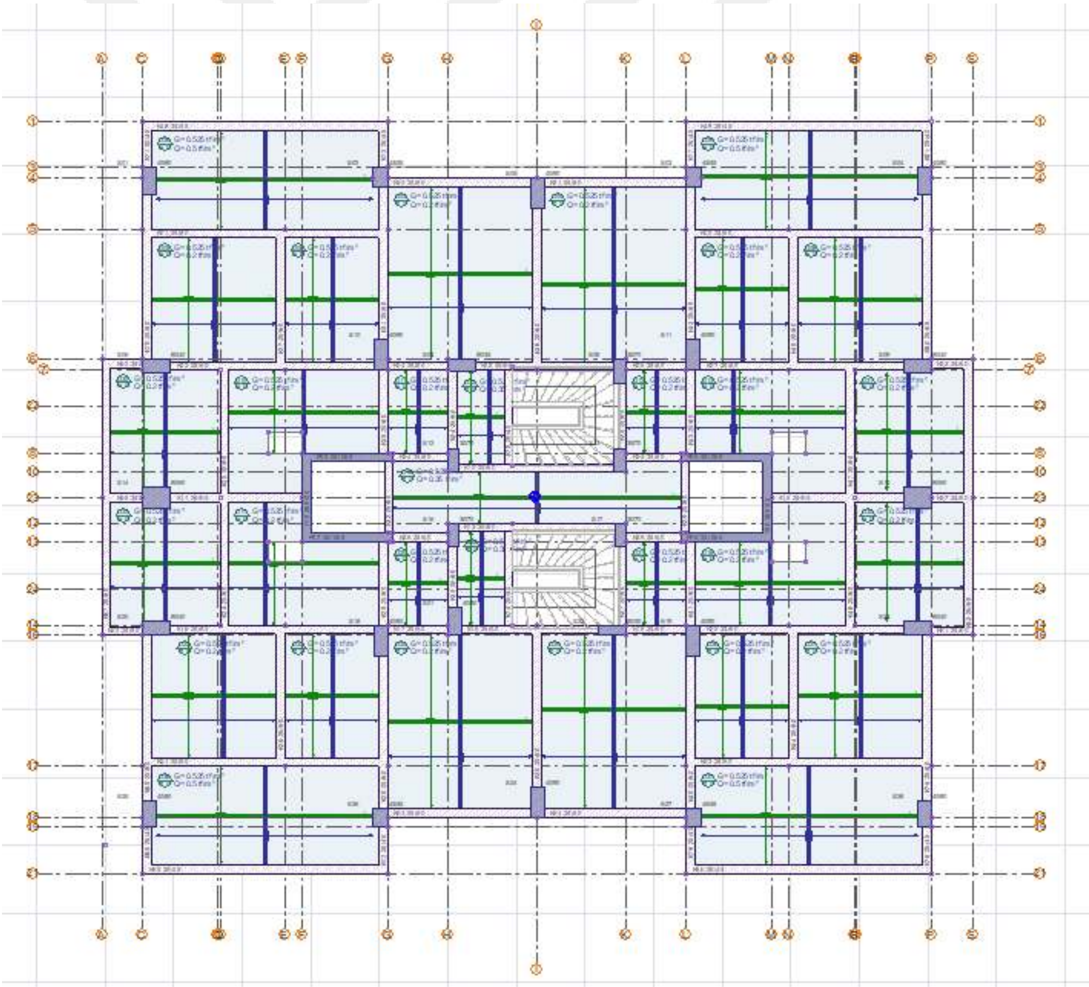
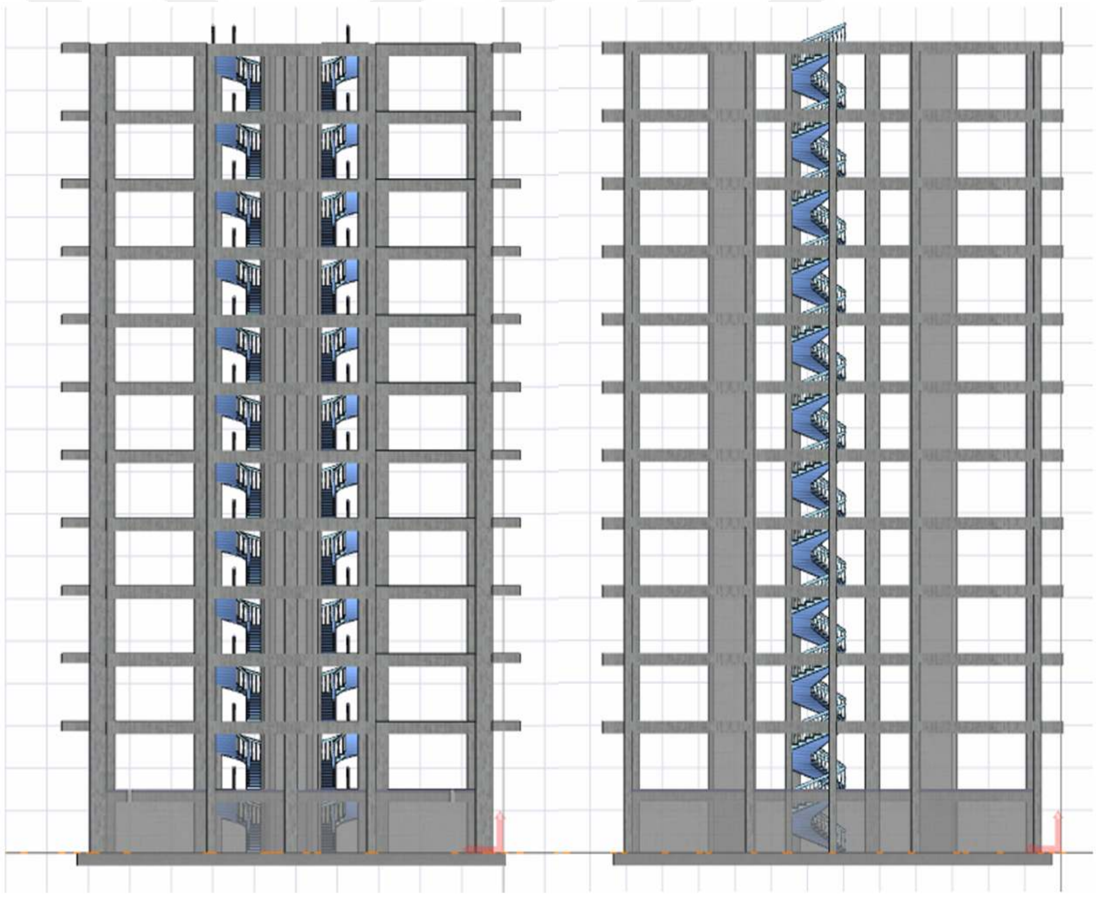


Figure 3.2 Ground Floor Plan

The structural system and other structural elements of the building have been sized based on the current TBDY-2018 and TS 500 regulations. Spectrum curves of the structures were created with the local points selected with the Turkey Earthquake Maps Interactive Web Application, and an earthquake hazard report was created, and the acceleration time values obtained with this report and the earthquake response spectrum curve formed at the earthquake level (DD-2) were designed.

The structures are designed in dimensions of 22.1 x 25.4 m. Each building; It has 12 floors in total, consisting of a basement, a commercial and ten normal floors, and each floor has a 510 m^2 floor area. Separate earthquake response spectrum curves were created for each case in three different locations, L1, L2 and L3, and 4 different Soil classes, ZA, ZB, ZC and ZD.



(a) **(b)**

Figure 3.3 (a) Side view of the model, (b) Front view of the model

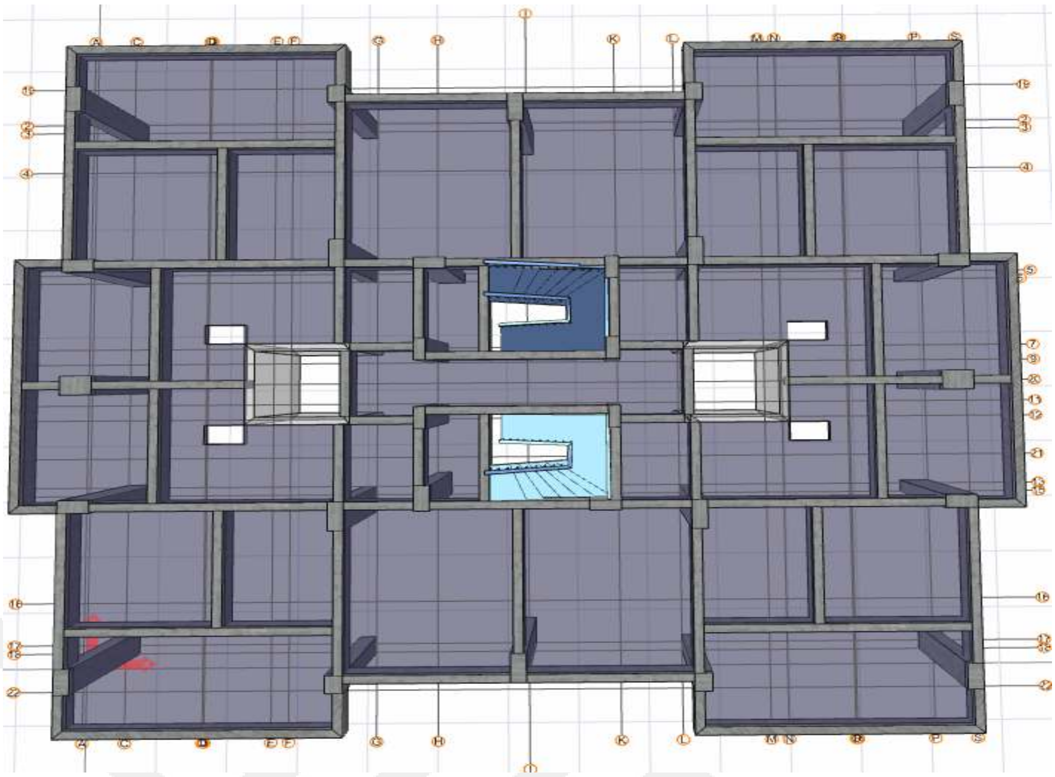


Figure 3.4 Top view of the model

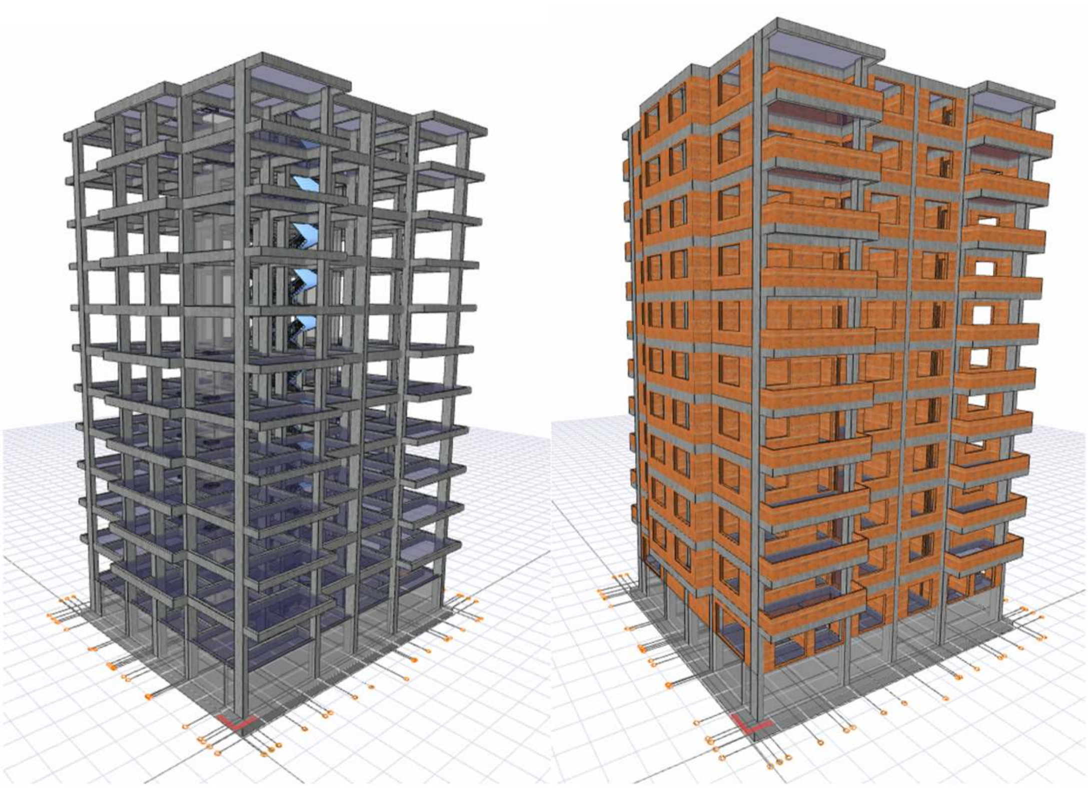


Figure 3.5 3D views of the model

A total of twelve analysis models were created to better understand the effects of the aforementioned locations and Soil classes, , on the analysis results. These analysis models are named Model-1 through Model-12 and each one contains a different set of variables. The variables for each of the 12 analysis models are detailed in Table 3.2. Additionally, the variables in the analysis models are further detailed in the following sections.

The impact of local Soil classifications on the destruction and damage caused by earthquakes has been a debated topic in structural engineering for years. This research aims to provide significant contributions to the field of structural design and earthquake risk management by examining in detail the effect of PGA, a measure of earthquake severity, on reinforced concrete structures under varying local Soil conditions.

Table 3.2 Analysis models and their variables

Model	**Location**	**Soil Class**	**PGA**	**Group**
1	L1	ZA	0.140	
2	L2	ZA	0.286	Group 1
3	L3	ZA	0.384	
4	L1	ZB	0.140	
5	L2	ZB	0.286	Group 2
6	L3	ZB	0.384	
7	L1	ZC	0.140	
8	L2	ZC	0.286	Group 3
9	L3	ZC	0.384	
10	L1	ZD	0.140	
11	L2	ZD	0.286	Group 4
12	L3	ZD	0.384	

3.9 Analysis Parameters

3.9.1 Determination of Materials Used in Buildings and Their Properties

In the load-bearing systems of reinforced concrete structures, the materials used play a critical role in ensuring the structural integrity and safety of the entire system. Specifically, the use of reinforcing steel and concrete are essential components in these systems, and as such, their mechanical properties must be carefully considered.

The following materials are used in all of the load-bearing systems of reinforced concrete structures. Materials S420 for reinforcing steel and C30 for concrete were used. According to TS500, the mechanical properties of these components are given in Tables 3.3 and 3.4.

Table 3.3 Concrete properties used in the building

Concrete Grade	Characteristic conc. Comp. Strength (f_{ck})	Characteristic conc. Tensile Strength (f_{ctk})	Modulus of Elasticity (E_c)
C30	30 MPa	1.9 MPa	32000 MPa

Table 3.4 Properties of reinforcing steel used in construction

Reinforcement Grade	Min. Yield Strength (f_{yk})	Min. Tensile Strength(f_{su})	Min. Strain Failure(ε_{su})	Modulus of Elasticity (E_s)
S420	420 MPa	500 MPa	0.12 MPa	200000 MPa

3.9.2 Determination of Earthquake Ground Motion Levels

The earthquake ground motion level in this study was identified as DD-2, which refers to infrequent earthquake ground motion. The probability of surpassing the spectral magnitudes in 50 years is 10%, and the corresponding recurrence period is 475 years. DD-2 Earthquake Ground Motion is also referred to as the standard design earthquake ground motion [5].

The recurrence period of 475 years associated with DD-2 earthquake ground motion suggests that the structure needs to be designed to withstand ground motion events that are infrequent but have the potential to cause significant damage. Therefore, it is essential to carefully consider the seismic design parameters and the expected ground motion levels in the region when designing structures to ensure their safety and longevity in the event of an earthquake.

Table 3.5 Earthquake ground movement levels (TBDY) [5]

Earthquake Ground Motion Level-1 (DD-1)	It characterizes very rare earthquake ground motions with a 2% probability of exceeding pectoral magnitudes in 50 years and a corresponding recurrence period of 2475 years. This earthquake ground motion is also called the largest earthquake ground motion considered.
Earthquake Ground Motion Level-1 (DD-2)	It characterizes the infrequent earthquake ground motion in which the probability of exceeding the spectral magnitudes in 50 years is 10% and the corresponding recurrence period is 475 years. This earthquake ground motion is also called standard design earthquake ground motion.
Earthquake Ground Motion Level-1 (DD-3)	It characterizes frequent earthquake ground motions 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-1 (DD-4)	It characterizes very frequent earthquake ground motions with a 68% probability of exceeding spectral magnitudes in 50 years (50% in 30 years) and a corresponding recurrence period of 43 years. This earthquake ground motion is also called service earthquake ground motion.

3.9.3 Map Spectral Acceleration Coefficients and Local Ground Effect Coefficients

Earthquake-related ground motion spectra are defined in a standard way in relation to the map spectral acceleration and local ground effect coefficients, or by detailed earthquake hazard analyzes of the terrain, for a 5% damping value based on a given earthquake ground motion level. Dimensionless map spectral acceleration coefficients are defined within the scope of Turkey Earthquake Hazard Maps for four different earthquake ground motion levels specified in table 3.5. These are the short period map spectral acceleration coefficient Ss and the map spectral acceleration coefficient S_1 for the 1.0 second period. This defined map spectral acceleration coefficients S_S and S_1 are converted to the design spectral acceleration coefficients S_{DS} and S_{D1} as follows;

$$S_{DS} = S_S F_S$$

$$S_{D1} = S_1 F_1 \tag{3.2}$$

As seen in Table 3.6 and Table 3.7 below, F_S shows the local ground effect coefficients for the short period region, and F_1 shows the local ground effect coefficient for the 1.0 second period [5].

Table 3.6 Local ground impact Coefficient for the short period zone F_S (TBDY) [5]

Local Ground Class	*Local Ground Impact Coefficient for the short period zone 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 ground behavior analysis will be done.* **(see 16.5)**					

Table 3.7 Local ground effect coefficient for 1.0 second period F_1(TBDY) [5]

Local Ground Class	*Local Ground Effect Coefficient for 1.0 second period 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 ground behavior analysis will be done.* **(see 16.5)**					

In Table 3.1 (Vs) 30 = 760 m/s corresponds to the intermediate boundary of the reference Soil condition ZB and ZC Soil classes. Accordingly, the local ground effect coefficients F_S and F_1 given in Table 3.6 and Table 3.7 are; It takes values less than 1.0 in ZA and ZB Soil classes, and greater than 1.0 in ZC, ZD and ZE Soil classes. As can be seen in Table 3.6 and Table 3.7, the decrease in F_S and F_1 values as the S_S and S_1 values increase is the result of nonlinear deformations in the ground as the earthquake effect increases.

3.9.4 Determination of Local Soil Classes

In this study, four clasas of local Soil classes, namely ZA, ZB, ZC and ZD, were studied. In Section 4.1, the latitude and longitude information of these locations as well as the ground parameters are specified.

3.9.5 Calculation of Design Spectrum Periods

In this study, the motion level for the DD-2 earthquake-related location is defined in Eq. (3.3) in terms of gravitational acceleration (g) depending on the natural ground dominant vibration period, and the horizontal elastic design spectral accelerations Sae(T), which are the coordinates of the horizontal elastic design acceleration spectrum.

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

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

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

$$S_{ae}(T) = \frac{S_{D1} T_L}{T^2} \qquad (T_L \le T) \qquad (3.3)$$

In this study, the terms S_{DS} and S_{D1} represent the design spectral acceleration coefficients. These coefficients are important in determining how much a structure will be affected during seismic activity. Additionally, the natural vibration period T is another important factor for a structure. The horizontal design spectrum corner periods T_A and T_B are dependent on the S_{DS} and S_{D1} values and are used to calculate the design spectrum. Determining these design parameters is crucial for ensuring the safety and reliability of structures under earthquake loading

$$T_A = 0.2\frac{S_{D1}}{S_{DS}} \quad ; \quad T_B = \frac{S_{D1}}{S_{DS}} \qquad (3.4)$$

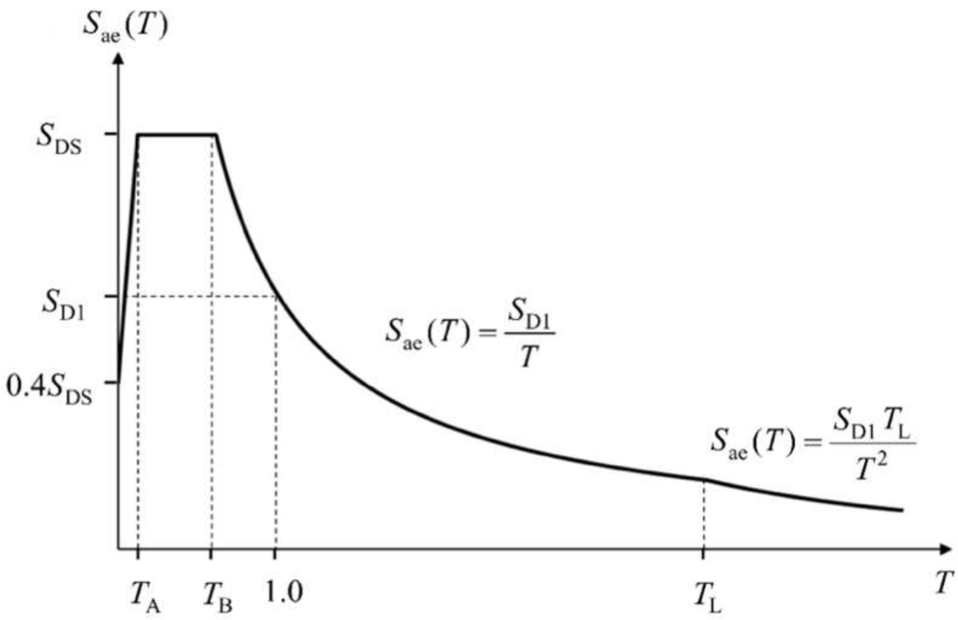


Figure 3.6 Graph of horizontal elastic design acceleration spectrum.

The period during which the ground naturally vibrates is called the ground dominant vibration period. The period is ground vibrations in the range of 0.05 to 2 seconds, caused by natural or artificial factors. The maximum number of repetitions of a certain period in a given area. Depending on the prevailing ground vibration period, the lower vibration period T_A and the upper vibration period T_B, Eq. It is calculated as shown in (3.3) and Equation (3.4). In this study, the Calculation of T_A and T_B Design Spectrum Periods will be made through the AFAD Turkey Earthquake Hazard Maps Interactive Web Application, together with satellite images of each location. The naming of the study locations will be shown as L1, L2, L3 for convenience during the study, and L1; Location-1, L2; Location-2, L3; It represents location-3. The ground motion level of the earthquake, the local ground class and the coordinates of the place where the structures will be built, as shown below, after entering the latitude and longitude, the coordinates of the relevant locations, the Spectral Acceleration Coefficients and Ground Acceleration by the application for the earthquake ground motion level and ground classes, Local Ground Effect Coefficients, Design Spectral Acceleration Coefficients, Horizontal Elastic Design Spectrum Periods (T_A and T_B Values), maximum ground acceleration and ground speed are calculated in the following tables.

Table 3.8 Earthquake parameters of the study locations

Location	Latitude	Longitude	S_S	S_1	PGA	PGV
L1	41.974435^0	34.959916^0	0.321	0.135	0.140	11.073
L2	39.771041^0	30.51427^0	0.673	0.173	0.286	16.266
L3	37.250828^0	37.01125^0	0.918	0.255	0.384	25.075

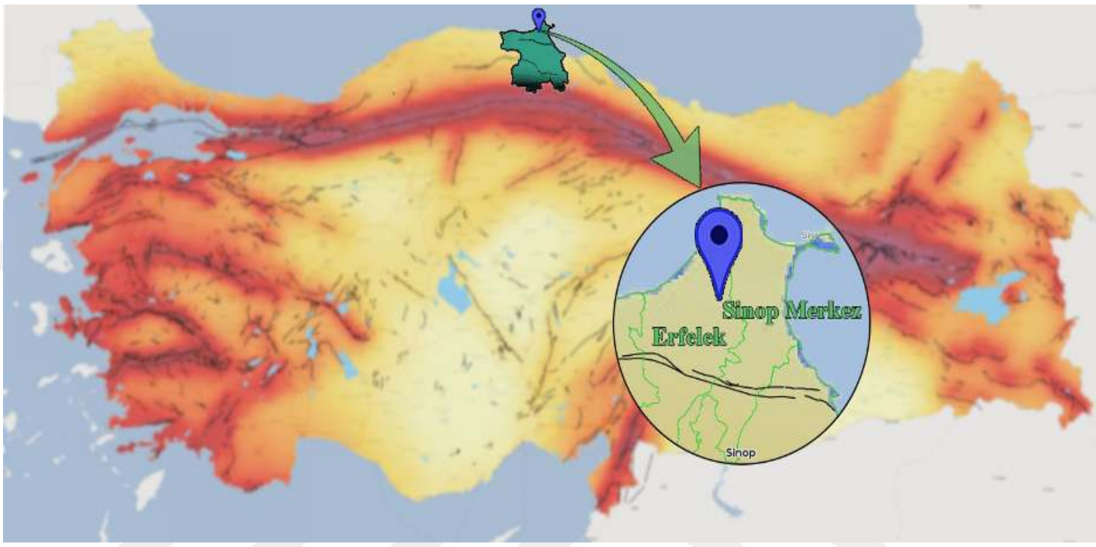


Figure 3.7 Map view of the L1 area

The L1 location is situated in the Erfelek district of Sinop, and the nearest fault line is located 17.45 km away from its position.

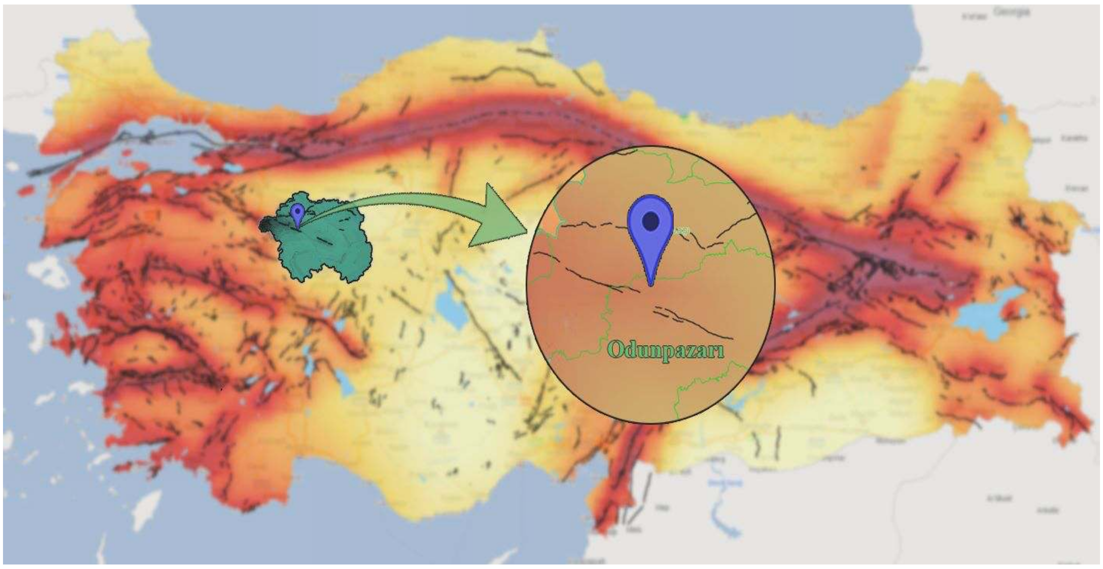


Figure 3.8 Map view of the L2 area

The L2 location is situated in the Odunpazarı district of Eskişehir, and the nearest fault line is located 2.58 km away from its position.

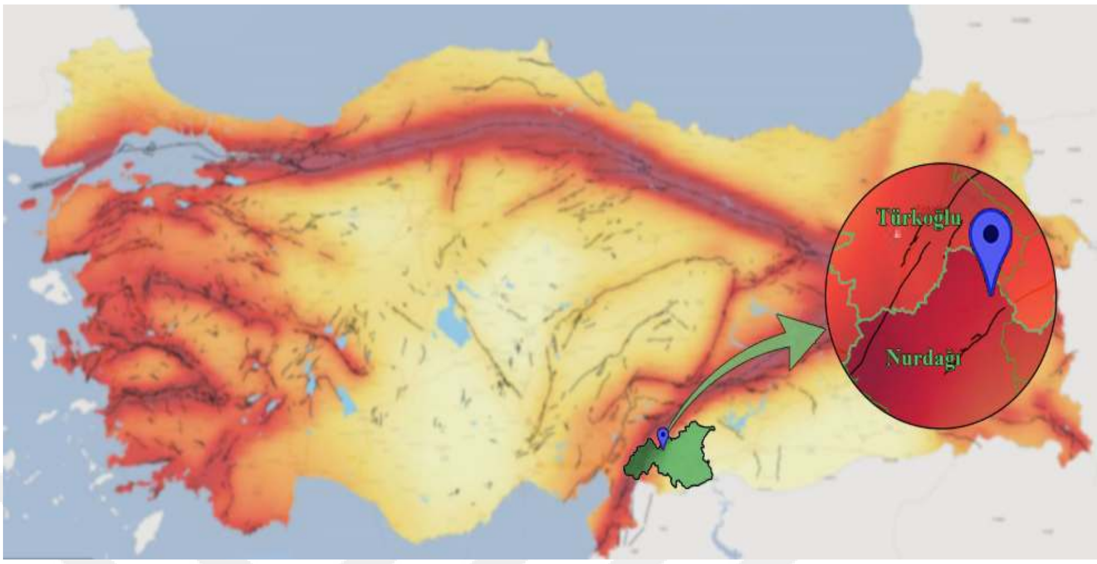


Figure 3.9 Map view of the L3 area

The L3 location is situated in the Nurdağı district of Gaziantep, and the nearest fault line is located 1.52 km away from its position.

Table 3.9 Spectral acceleration coefficients and spectrum characteristic periods of locations according to soil class

Location	Soil Class	S_{DS}	S_{D1}	T_A (S)	T_B (S)
L1	ZA	0.256	0.108	0.084	0.421
L1	ZB	0.288	0.108	0.075	0.374
L1	ZC	0.417	0.202	0.097	0.485
L1	ZD	0.495	0.314	0.127	0.635
L2	ZA	0.538	0.184	0.051	0.257
L2	ZB	0.605	0.138	0.046	0.288
L2	ZC	0.836	0.273	0.065	0.327
L2	ZD	0.849	0.389	0.092	0.459
L3	ZA	0.734	0.204	0.056	0.278
L3	ZB	0.826	0.204	0.049	0.247
L3	ZC	1.101	0.382	0.069	0.347
L3	ZD	0.849	0.389	0.092	0.459

3.9.6 Determination of Building Use Class and Building Importance Factor

The building usage classes defined according to the usage characteristics of the building to be designed under the effect of earthquake and the building importance coefficients selected for these are shown in Table 3.10. Since the building we chose in this study is a residential type, the building usage class was determined as BKS=3 and the building importance coefficient was determined as I=1.0

Table 3.10 Building use classes and building importance factors (TBDY) [5]

Building Use Class	Purpose of Using the Building	Building Importance Factor (I)
BKS=1	**Buildings that need to be used after an earthquake, buildings where people stay for a long time and intensely, buildings where valuable goods are stored and buildings containing dangerous substances** **a)** Buildings that must be used immediately after an earthquake (Hospitals, dispensaries, health centers, fire brigade buildings and facilities, Post Offices and other communication facilities, transportation stations and terminals, power generation and distribution facilities, province, district and municipality administration buildings, first aid and disaster planning stations) **b)** Schools, other educational buildings and facilities, dormitories and dormitories, military barracks, prisons, etc. **c)** Museums **d)** Toxic, explosive, flammable, etc. buildings where substances with properties are located or stored	1.5
BKS=2	**Buildings where people are concentrated for a short time** Shopping centers, sports facilities, cinemas, theatres, concert halls, places of worship, etc.	1.2
BKS=3	**Other buildings** Other buildings that are not included in the definitions given for BKS=1 and BKS=2 (Houses, workplaces, hotels, building type industrial structures, etc.)	1.0

3.9.7 Determination of Earthquake Design Class

The building usage class is determined based on the building's intended purpose. For example, a hospital or school building has a different usage class than an office building. Based on this usage class, the relevant spectral acceleration coefficient and short-period design spectral acceleration coefficient are determined. These parameters are used to determine the acceleration values that the building will be subjected to in an earthquake.

These acceleration values are compared to a parameter called the earthquake design class (DTS). The earthquake design class is used to determine the minimum earthquake load that will be used in the building's design. This class is determined based on the relevant spectral acceleration coefficient and short-period design spectral acceleration coefficient. The DTS value is a numerical value that increases as it represents a region with lower seismic hazard, while decreasing values represent regions with higher seismic hazard.

In summary, the design and construction of buildings located in earthquake-prone areas should take into account earthquake parameters such as building usage class, relevant spectral acceleration coefficient, and short-period design spectral acceleration coefficient. The earthquake design class determined by using these parameters is important for increasing the building's earthquake resistance. Since the DTS values of buildings in areas with the highest earthquake hazard are the lowest, special attention should be paid to the design of buildings in these areas.

Table 3.11 Earthquake design classes (TBDY) [5]

Short Period Design Spectral Acceleration Coefficient (S_{DS}) at DD-2 Earthquake Ground Motion Level	Building Use Class	
	BKS=1	BKS=2,3
$S_{DS} < 0.33$	DTS = 4a	DTS =4
$0.33 \leq S_{DS} < 0.50$	DTS = 3a	DTS = 3
$0.50 \leq S_{DS} < 0.75$	DTS = 2a	DTS = 2
$0.75 \leq S_{DS}$	DTS = 1a	DTS = 1

In this study, the data of the aforementioned locations where the buildings will be designed and the Short Period Design Spectral Acceleration Coefficients at the DD-2 Level are given in Table 3.9, and depending on these coefficients, as indicated in Table 3.11, the building usage class for the residential building, in short, Table 3.12 below presents the design classes.

Table 3.12 Building use classes and earthquake design classes for each analysis

Model	Soil Class	S_{DS}	BKS	DTS
1	ZA	0.256	3	4
2	ZA	0.538	3	2
3	ZA	0.734	3	2
4	ZB	0.288	3	4
5	ZB	0.605	3	2
6	ZB	0.826	3	1
7	ZC	0.417	3	3
8	ZC	0.836	3	3
9	ZC	1.101	3	1
10	ZD	0.495	3	3
11	ZD	0.849	3	1
12	ZD	0.849	3	1

3.9.8 Determination of Building Height Classes

In seismic design, it is important to consider the potential seismic hazards that a building may be exposed to and design the building's structural system to resist those hazards. One key factor in seismic design is the height of the building, as taller buildings are generally more susceptible to damage during earthquakes.

To account for this, buildings are divided into eight Building Height Classes, based on their total height, which is the vertical distance from the lowest level of the building to the highest point of the roof. The specific height limits for each Building Height Class depend on the Earthquake Design Class of the building, which is determined by the seismic hazard level of the building's location.

Table 3.13 provides the height limits for each Building Height Class for various Earthquake Design Classes. These height limits are intended to ensure that buildings of a certain height are designed to resist the potential seismic hazards they may face. It is important for engineers and architects to consider these height limits when designing buildings in seismically active areas.

Table 3.13 Building height ranges defined by building height classes and earthquake design classes (TBDY) [5]

Building Height Class	Building Height Ranges Defined by Building Height Classes and Earthquake Design Classes [m]		
	DTS = 1, 1a, 2, 2a	DTS = 3, 3a	DTS = 4, 4a
BYS=1	$H_N > 70$	$H_N > 91$	$H_N > 105$
BYS=2	$56 < H_N \leq 70$	$70 < H_N \leq 91$	$91 < H_N \leq 105$
BYS=3	$42 < H_N \leq 56$	$56 < H_N \leq 70$	$56 < H_N \leq 91$
BYS=4	$28 < H_N \leq 42$	$42 < H_N \leq 56$	
BYS=5	$17.5 < H_N \leq 28$	$28 < H_N \leq 42$	
BYS=6	$10.5 < H_N \leq 17.5$	$17.5 < H_N \leq 28$	
BYS=7	$7 < H_N \leq 10.5$	$10.5 < H_N \leq 17.5$	
BYS=8	$H_N \leq 7$	$H_N \leq 10.5$	

The floor heights of the model we designed in this study; The total height of the 12-storey reinforced concrete building is 38.20 m, while it is 3 m in the basement and 3.2 m in the other 11 floors, and the Building Height Classes are determined in Table 3.14 for each location depending on the Earthquake Design Classes.

Table 3.14 Building height classes depending on the earthquake design classes (TBDY) [5]

Model	**DTS**	**H_N**	**BYS**
1	4	38.20 **m**	5
2	2	38.20 **m**	4
3	2	38.20 **m**	4
4	4	38.20 **m**	5
5	2	38.20 **m**	4
6	1	38.20 **m**	4
7	3	38.20 **m**	5
8	3	38.20 **m**	5
9	1	38.20 **m**	4
10	3	38.20 **m**	5
11	1	38.20 **m**	4
12	1	38.20 **m**	4

The Performance Targets and Building Performance Levels for structural systems of buildings, subjected to earthquakes, are explained under four distinct headings

These headings are;

- The Uninterrupted Use (UU) Performance Level,
- The Limited Damage (LD) Performance Level,
- The Controlled Damage (CD) Performance Level
- Prevention of Collapse (PC) Performance Level.

Damages that do not cause structural damage to the structural elements of the structure's structural elements or that the damage is insignificant represents the Uninterrupted Use (UU) Performance Level. The Limited Damage (LD) Performance

Level, in which a limited level of damage occurs in the structure due to the effect of earthquake forces, is called. The Controlled Damage (CD) Performance Level, which is generally determined as the damage level that can be repaired in the structure. Prevention of Collapse (PC) Performance Level, the collapse of some or all of the structure under the effects of earthquakes is prevented [5].

Table 3.15 Performance targets and evaluation/design approaches for new cast-in-situ reinforced concrete, pre-engineered reinforced concrete and steel buildings (TBDY) [5]

Earthquake Ground Motion Level	DTS = 1, 1a ,2 ,2a ,3, 3a, 4, 4a		DTS = 1a, 2a	
	Normal Performance Target	Evaluation/Design Approach	Advanced Performance Target	Evaluation/Design Approach
DD-3	-	-	LD	DAF**
DD-2	CD	DBS*	CD	DBS*
DD-1	-	-	CD	DAF**

In this study, for earthquake design classes determined for each location, as stated in Table 3.15, the normal performance target for the DD-2 earthquake ground motion level was determined to be the controlled damage performance level, and the evaluation design approach was determined to be designed according to strength.

In approaches that adopt Design Based on Strength (DBS), reduced seismic loads are defined relating to the ductility of the structural system that is defined for a specific adopted performance target. According to these, a linear earthquake analysis of the carrier system is made under reduced seismic forces and the element reduced internal forces found by these calculations, when necessary, by emphasizing the excess of strength and the values required for strength are obtained by combining them with internal forces from other loads.

3.9.9 Determining the Carrier System Type

According to the Turkish Building and Earthquake Code, some general rules should be followed and these rules should be taken into account in the arrangement of the structural systems of the buildings in order to be able to design them properly under the influence of earthquake forces. These rules are generally, being a plain and simple carrier system, being regular and at the same time symmetrical design, ensuring more dependency in the system between the elements that make up the structural carrier system, sufficient ductility of the carrier system elements, ensuring adequate slab rigidity between floors and transition floors and their strength. In this sense, it is necessary to stay away from irregular carrier systems in plan and vertically as much as possible.

In summary; In order to ensure that the behavior of the building under the influence of earthquake forces is predictable, the main condition of the design under the influence of earthquake is that this system should be plain, understandable and simple.

Twelve model structures, named Model 1-12, which we have designed in this study, have been determined as a reinforced concrete carrier system with these features and the type of building carrier system, taking into account the above-mentioned issues, and their analyzes have been made accordingly.

3.9.10 Determining the Diaphragm Type

In the design of floor slabs as a rigid diaphragm on their own coordinates, the floor masses are defined in such a way that they correspond to three independent rigid in-plane degrees of freedom at the actual nodal point at the center of mass of the floors. In this study, our system was designed as a semi-rigid diaphragm.

3.9.11 Determination of Ductility Level

Reinforced concrete carrier systems, in terms of their ductility; It is divided into three types as structural systems with limited ductility level, carrier systems with high ductility level and carrier systems with mixed ductility level. In this study, buildings with high ductility level were designed.

3.9.12 Determination of Structural System Behavior and Strength Excess Coefficients

In terms of design based to strength (DBS), the building load-bearing systems to which the calculation conditions shown in this section can be applied, and the Building Height Classes and Structure Ductility Levels allowed on behalf of the structure carrier systems are shown in detail in Figure 3.16 below.

In all analysis models, the structural system was determined as a framed system, and the coefficient of behavior (R) of the structural system in the X and Y directions was defined as 7, and the coefficient of excess strength was defined as 2.5.

Table 3.16 Structural System Behavior and Strength Excess Coefficients

Structural Systems	Carrier System Behavior Coefficient **R**	Strength Excess Coefficient **D**	BYS
A. Reinforced Concrete Structures			
A1. High Ductility			
A15. Special Shear wall Systems with special moment frames (See 4.3.4.5)	7	2.5	BYS≥2

CHAPTER 4
ANALYSIS RESULTS

4.1 The Evaluation of Structural Systems

Based on the analysis, we examined the variations in building periods, base shear forces, relative story drifts, earthquake loads, horizontal loads acting on floors, earthquake moments, and approximate building costs depending on changes in Soil class and Peak Ground Acceleration rates. These results are crucial in determining the performance of the structural systems in the event of an earthquake and can provide valuable insights into the resilience of the building models.

The examination of the building periods is a critical factor in understanding the building's dynamic behavior under seismic activity. By analyzing the base shear forces and relative story drifts, we can assess the structural integrity of the building models under various seismic conditions. The earthquake loads and horizontal loads acting on floors are essential in determining the potential damage to the building models, while the earthquake moments provide an insight into the torsional effects experienced by the building models.

Finally, we analyzed the approximate building costs and their variations based on the changes in Soil class and Peak Ground Acceleration rates. This analysis is crucial in determining the feasibility of designing and constructing buildings in different locations with varying Soil conditions.

Overall, the results and risk evaluation of this study provides valuable insights into the performance of the structural systems of the building models under seismic activity. By examining the variations in critical factors such as building periods, base shear forces, relative story drifts, earthquake loads, horizontal loads acting on floors, earthquake moments, and approximate building costs, we can develop a better understanding of the resilience of the building models and make informed decisions about designing and constructing buildings in seismic-prone areas.

Table 4.1 The Coordinates of the locations used in the study

Location	Latitude	Longitude
L1	41.974435^0	34.959916^0
L2	39.771041^0	30.51427^0
L3	37.250828^0	37.01125^0

Table 4.2 Analysis models and soil parameters

Model	Location	Soil Class	S_{DS}	S_{D1}	T_A (S)	T_B (S)	PGA
1	L1	ZA	0.256	0.108	0.084	0.421	0.140
2	L2	ZA	0.538	0.184	0.051	0.257	0.286
3	L3	ZA	0.734	0.204	0.056	0.278	0.384
4	L1	ZB	0.288	0.108	0.075	0.374	0.140
5	L2	ZB	0.605	0.138	0.046	0.288	0.286
6	L3	ZB	0.826	0.204	0.049	0.247	0.384
7	L1	ZC	0.417	0.202	0.097	0.485	0.140
8	L2	ZC	0836	0.273	0.065	0.327	0.286
9	L3	ZC	1.101	0.382	0.069	0.347	0.384
10	L1	ZD	0.495	0.314	0.127	0.635	0.140
11	L2	ZD	0.849	0.389	0.092	0.459	0.286
12	L3	ZD	0.849	0.389	0.092	0.459	0.384

4.1.1 Building Earthquake Period Values

In the field of civil engineering, the period of a structure is a critical parameter in determining its response to seismic forces. The period is affected by several factors such as the stiffness of the structure, its mass, and the Soil conditions at the site of construction.

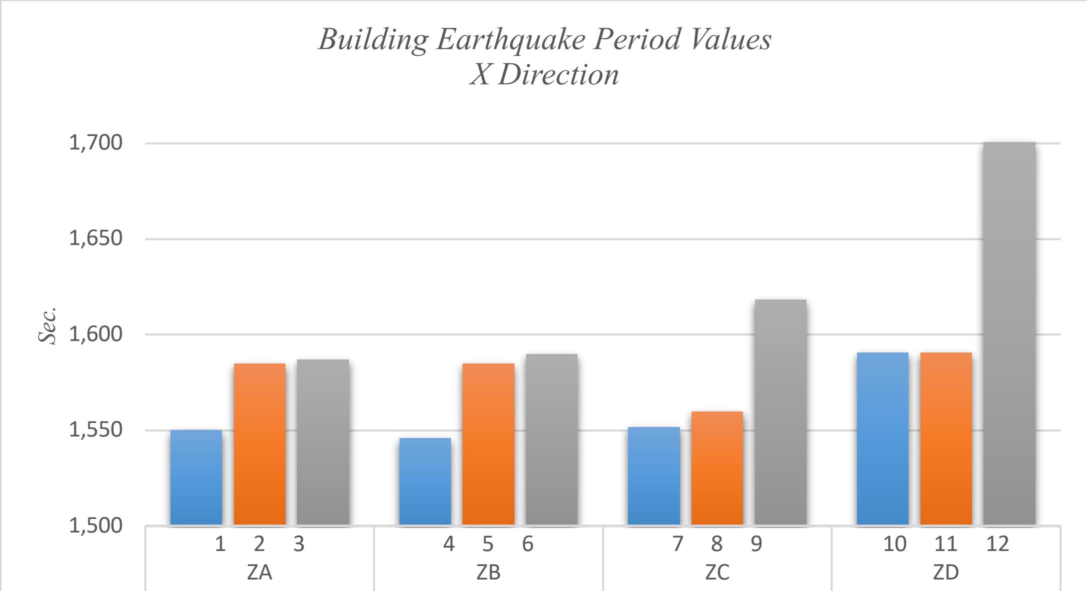
The period is the time it takes for a complete movement of the structure to occur, starting from the initiation of movement under the influence of external forces until the structure returns to its original position. A shorter period indicates a more rigid structure, while a longer period indicates a more flexible structure.

Structures with shorter periods are less likely to experience significant damage during an earthquake since they move less, while structures with longer periods are more susceptible to damage because they move more. The period of a structure is also used to determine the earthquake loads that the structure can withstand without sustaining damage.

One important consideration in the design of structures is to ensure that the periods in both the x and y directions are equal or very close to each other. This is because differences in period between the two directions can lead to torsional effects that can cause damage to the structure.

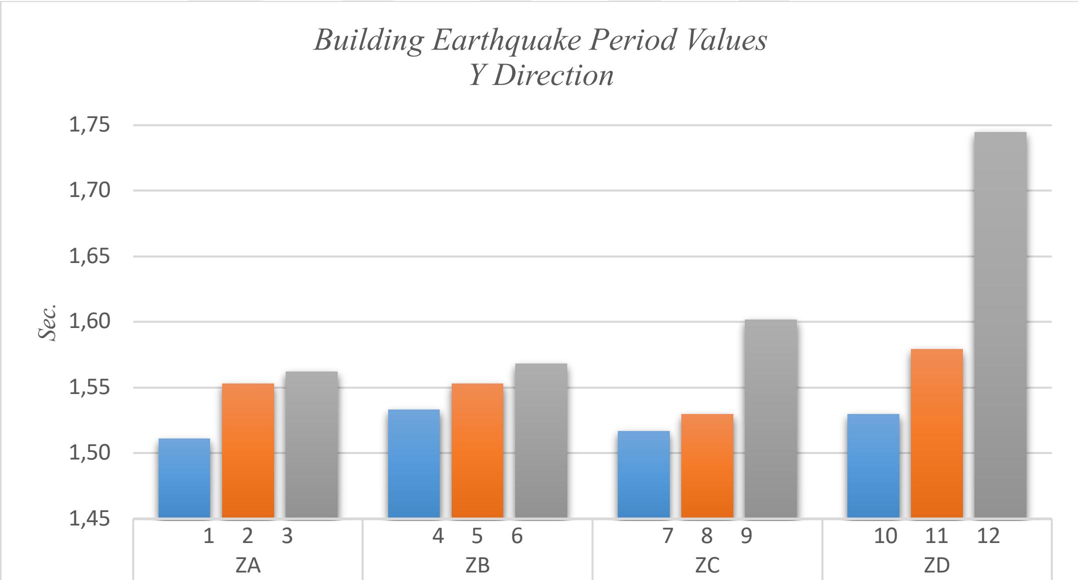
In addition to the stiffness and mass of the structure, the Soil conditions at the construction site also play a essential role in determining the structural period. Different Soil classes have varying levels of stiffness, which affects the period of the structure. Therefore, the period of a structure may vary depending on the location of the construction site and the Soil conditions at that site.

To ensure the safety and durability of structures in different locations, it is crucial to consider the local Soil conditions and design structures accordingly. The period is just one of several factors that engineers consider when designing structures to withstand seismic forces and other environmental loads. By carefully considering these factors, engineers can create safe and reliable structures that meet the needs of their communities



	1 2 3 ZA	4 5 6 ZB	7 8 9 ZC	10 11 12 ZD
L1	1,5501	1,5458	1,5517	1,5906
L2	1,5848	1,5848	1,5597	1,5906
L3	1,5868	1,5898	1,6182	1,7006

Figure 4.1 Building earthquake period values in X direction



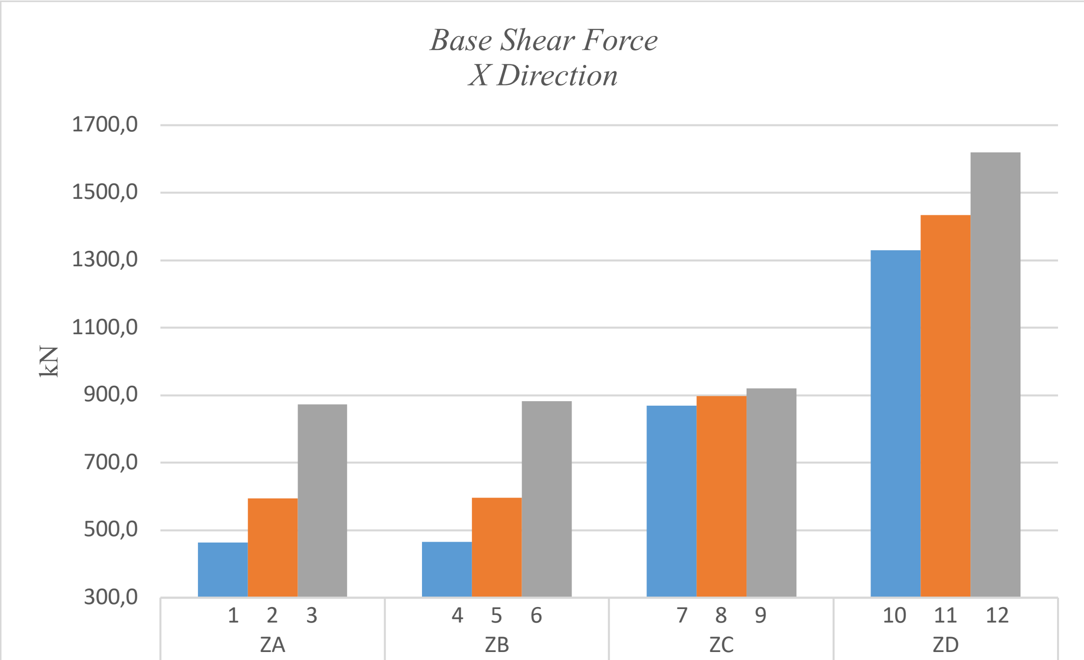
	1 2 3 ZA	4 5 6 ZB	7 8 9 ZC	10 11 12 ZD
L1	1,5110	1,5331	1,5168	1,5297
L2	1,5531	1,5531	1,5296	1,5791
L3	1,5620	1,5681	1,6018	1,7447

Figure 4.2 Building earthquake period values in Y direction

As the engineering parameter values of the Soil decreased, the structure period values in the x and y directions increased in all models designed according to the building types. That is, the engineering parameters of the Soil such as the bearing coefficient, bearing capacity and local Soil class used in the structural design phase of the Soil changed according to the locations. This variation decreases from L1 to L3, and Soil data tends to be lower. As a result of these data, we will examine the structure period values caused by the change of ground parameters depending on the locations of the structure we have designed. As the Peak Ground Acceleration value increased, the building period values for all building types showed an average increase of about 2%. The transition of the local Soil class from ZA to ZD showed an average increase of approximately 2% in the x and y direction periods in all analysis models. On the other hand, with both the deterioration of the local Soil class and the increase in the PGA value; The rate of increase between analysis Model-1 and analysis Model-12 was calculated as approximately 9% in the x direction and approximately 15% in the y direction. Although the period values are always higher in both the x and y directions in the structure designed in the L3 location, while it is higher in the X direction than in the Y direction in ZA, ZB and ZC Soil classes, it is higher in the y direction than in the x direction in the ZD Soil class. Since the analysis models are designed symmetrically, the x-direction and y-direction period values of each model are calculated quite similarly. When the same Soil classes are classified within themselves, the rate of increase in the amount of increase in the period value as the locations change in the ZD Soil class was the highest in both directions.

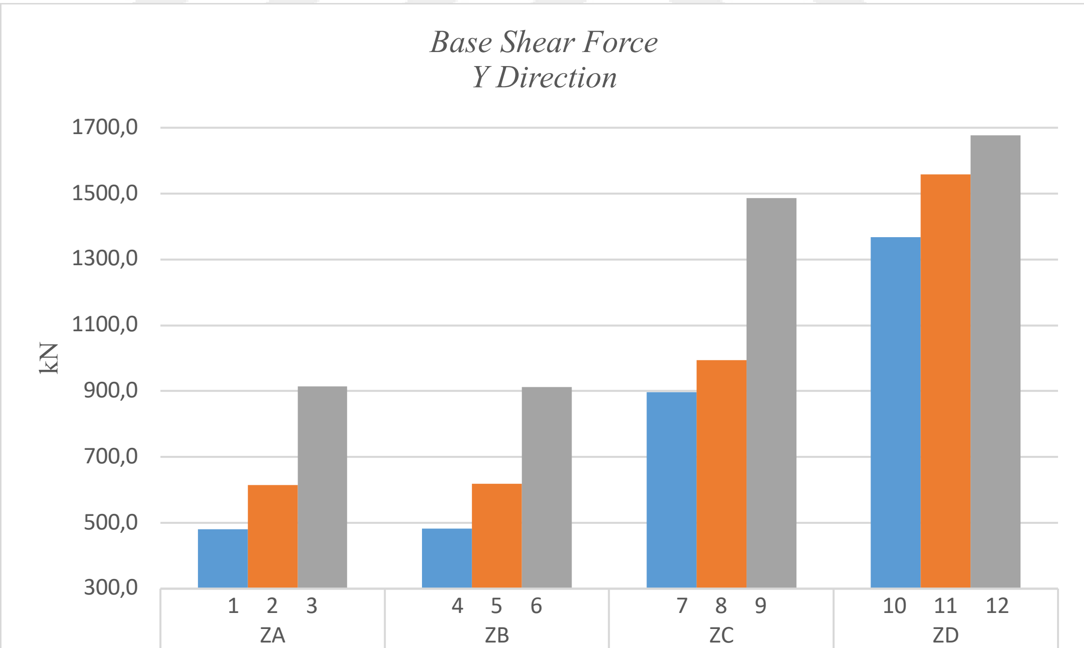
4.1.2 Base Shear Forces

In Figure 4.3 and Figure 4.4, the variation of base shear forces obtained from different local Soil classes and PGA in X and Y directions are given. It was observed that there was an increase in base shear forces obtained from ZA, ZB, ZC and ZD Soil classes and L1, L2 and L3 locations. Considering all locations, the increase in base shear force was between 85% and 186%. When the locations are examined, the location where the maximum increase in the base shear force occurs is L1, while the location where the least increase occurs is L3. Deterioration of Soil grade or increase in PGA value; causes an increase in the base shear force. When the results of the analysis were examined, it was determined that these two parameters also increased the rate of increase in the simultaneous deterioration. Briefly; It has been determined that there is an increase in the base shear force as the Soil class worsens and the PGA value increases, and it can be said that the amount of increase is not negligible. In addition, as can be seen in the graphs below, the simultaneous deterioration of the Soil class and PGA value increases this increase rate.



	1 2 3 ZA	4 5 6 ZB	7 8 9 ZC	10 11 12 ZD
L1	463,3917	465,4903	868,5809	1329,8700
L2	593,8260	596,5317	898,0538	1433,5645
L3	872,1328	881,5816	919,5068	1619,8654

Figure 4.3 Base shear force in X direction



	1 2 3 ZA	4 5 6 ZB	7 8 9 ZC	10 11 12 ZD
L1	480,2875	482,1135	896,2150	1367,5109
L2	615,4791	617,8209	994,3345	1559,1230
L3	913,9396	912,1548	1487,2648	1676,0085

Figure 4.4 Base shear force in Y direction

4.1.3 Relative Story Displacements

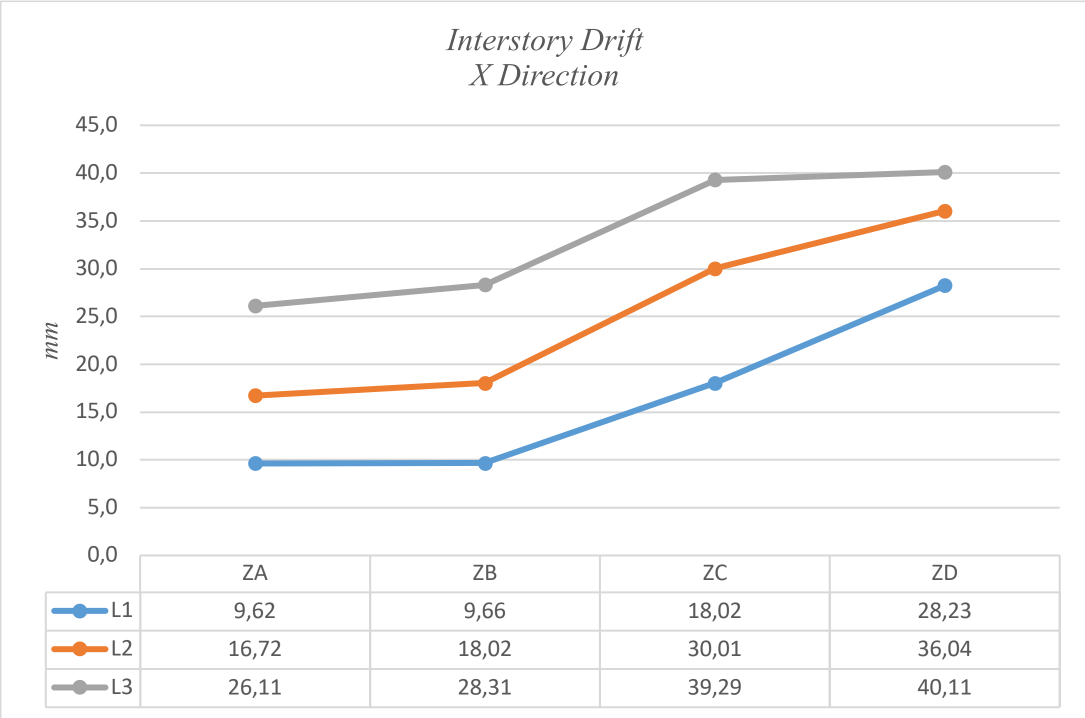
According to TBDY Section 4.9, the calculation of effective relative story displacements in buildings is made according to equation 4.1 [5].

$$\lambda \frac{\delta_{i,max}^{(x)}}{h_i} \leq 0.008\kappa \tag{4.1}$$

The coefficient of λ in this formula is expressed as the ratio of the elastic design spectral acceleration of the DD-3 earthquake ground motion defined on the AFAD website to the elastic design spectral acceleration of the DD-2 earthquake ground motion. These calculated values are detailed in the table 4.3 below. The coefficient κ in the equation is taken as 1 for reinforced concrete buildings. The relative story displacements values of the models in the numerical study, x and y directions are given in Figures 4.5 and 4.6. Calculated relative story drift values of all analysis models did not exceed the limit values.

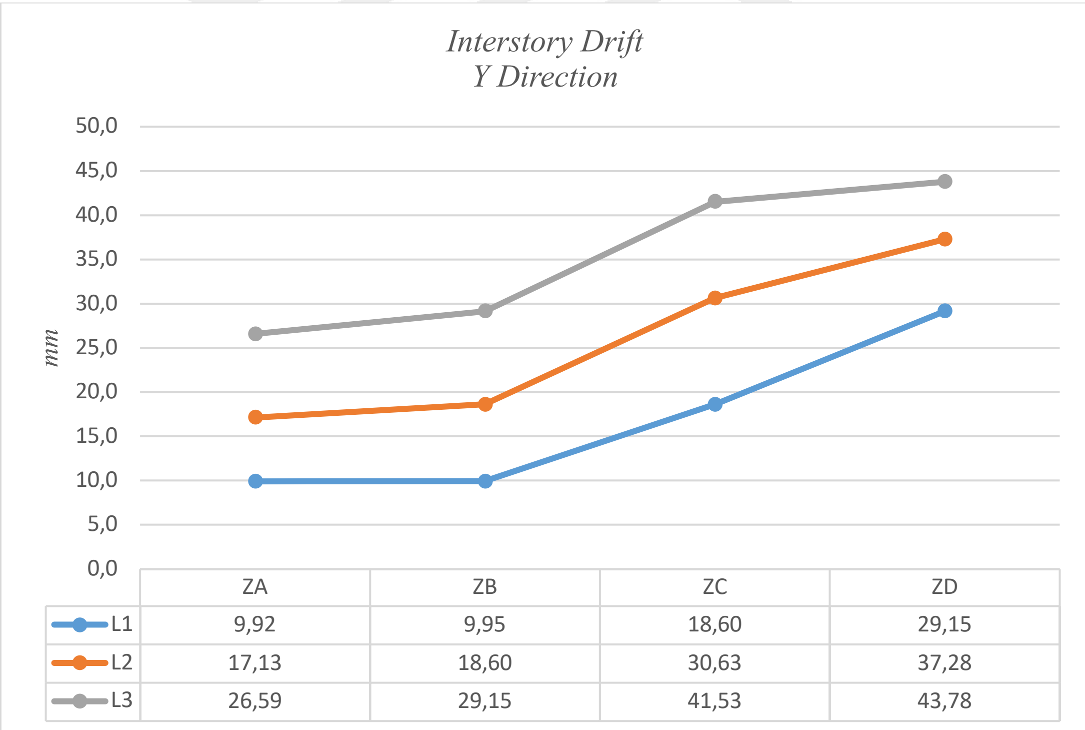
Table 4.3 Empirical coefficient used to constrain relative story displacements

Model No	λ for X Direction	λ for Y Direction
1	0.3852	0.3852
2	0.4046	0.4046
3	0.3333	0.3333
4	0.3852	0.3852
5	0.4046	0.4046
6	0.3333	0.3333
7	0.3852	0.3852
8	0.4046	0.4046
9	0.3333	0.3333
10	0.3968	0.3968
11	0.4308	0.4308
12	0.4308	0.4308



	ZA	ZB	ZC	ZD
L1	9,62	9,66	18,02	28,23
L2	16,72	18,02	30,01	36,04
L3	26,11	28,31	39,29	40,11

Figure 4.5 Relative story displacements in X direction



	ZA	ZB	ZC	ZD
L1	9,92	9,95	18,60	29,15
L2	17,13	18,60	30,63	37,28
L3	26,59	29,15	41,53	43,78

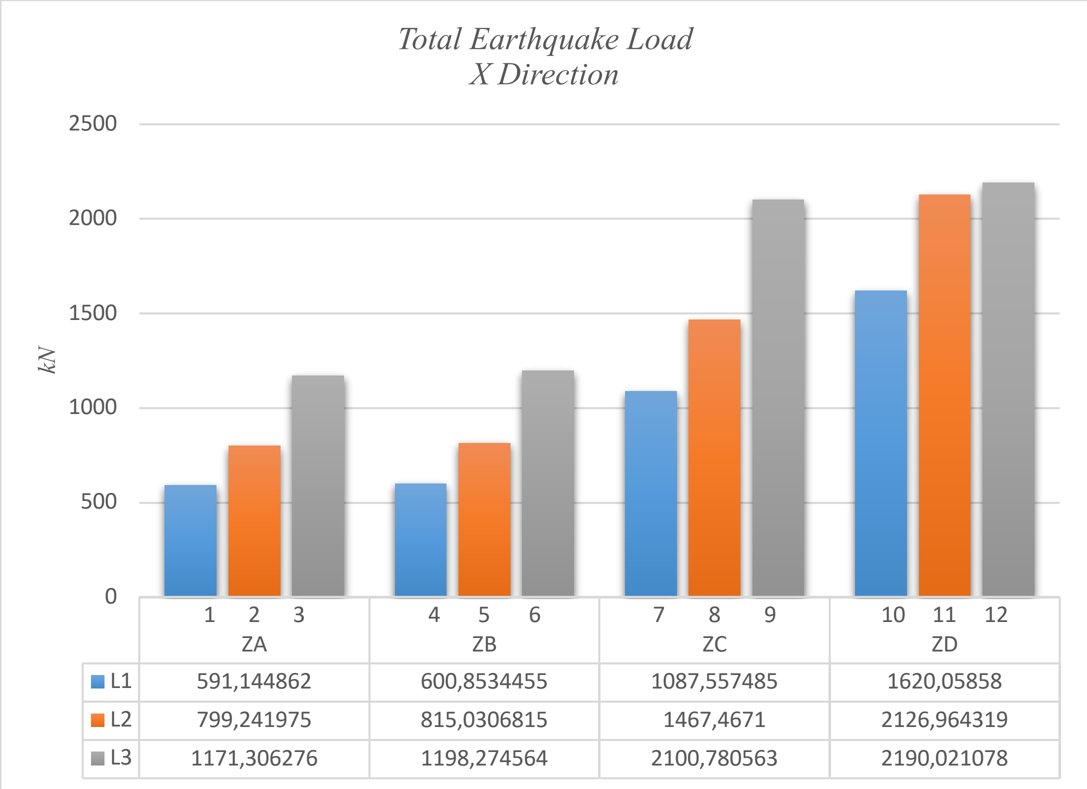
Figure 4.6 Relative story displacements in Y direction

In this analysis, the relative storey displacements of all floors were determined for all analysis models, and graphs and tables were created by taking the largest relative storey displacement occurring in the storeys during the evaluation phase. For all analysis models, an increase in floor displacements was observed with the change of Soil class, that is, the decrease in Soil bearing capacity. When chart 4.5 and chart 4.6 are examined, it is seen that these increases are parallel in x and y directions. The relative storey displacements of the analysis models at the L3 location have always been higher than the other analysis models. While the analysis models at the L2 location showed similar displacements in ZA, ZB and ZC Soil classes, it was determined that the relative floor drift amount increased significantly, with an average of 96% increase when switching from ZC Soil class to ZD Soil class. When we look at the analysis models in L1 location, there is almost no increase in the relative floor drift while passing from the ZA floor class to the ZB floor class, while a not negligible increase has been detected as the Soil class changes from the ZB Soil class to the ZD Soil class. In the analysis models at the L1 location, the average increase rate between Model-1 in ZA Soil class and Model-10 in ZD Soil class was calculated as 193%.

In other words, if these structural system behaviors are taken into consideration during the design phase of the reinforced concrete building, it is important to place the structural system elements proportionally in the x and y directions in order to have the necessary and sufficient rigidity of the structural system in response to any earthquake possibility.

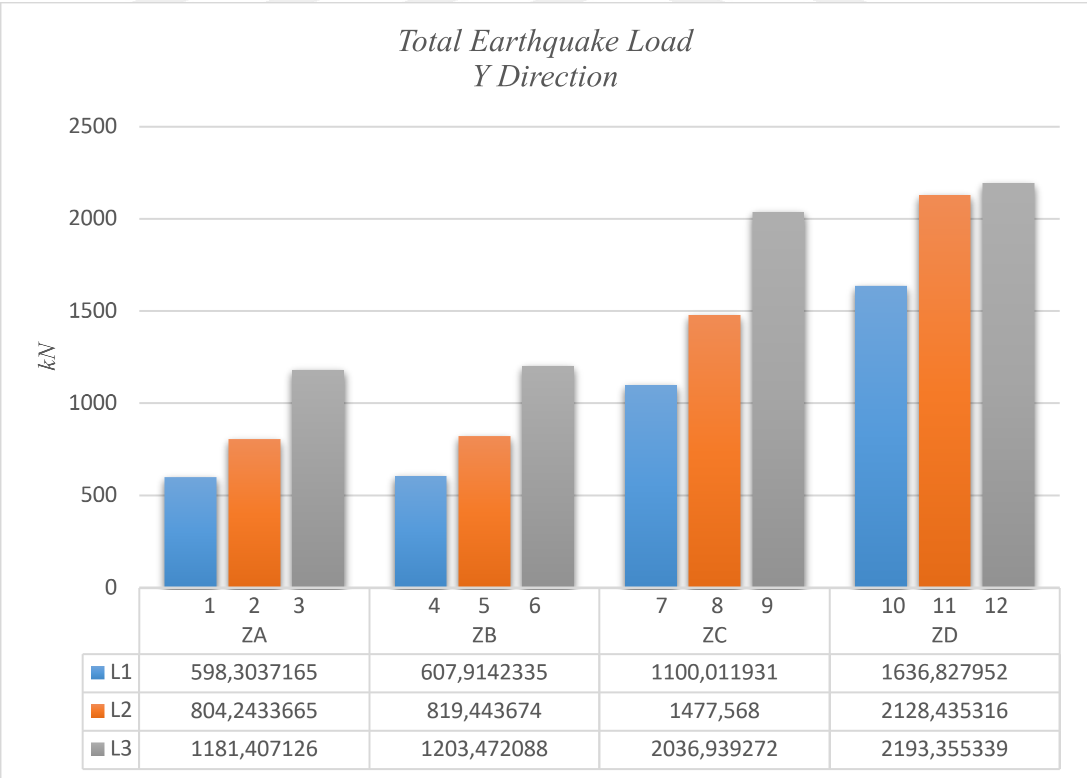
4.1.4 Earthquake Load

In this section, the earthquake load acting on the models is compared. When the total earthquake loads affecting all models are compared; As can be seen, Model-1 was subjected to the lowest load in both directions, while Model-12 was subjected to the highest load. With the effect of Soil classes and PGA, the average increase rate in both directions in earthquake loads was 260%. When the PGA value is kept constant, the greatest increase in earthquake loads was between Model-1 and Model-10 with an average of 174% at L1 location. When the Soil class is kept constant, the greatest increase in earthquake loads was found to be between Model-4 and Model-6 with an average of 99% in ZB Soil class. All earthquake loads are detailed in Figure 4.7 and Figure 4.8 for both directions.



	ZA	ZB	ZC	ZD
L1	591,144862	600,8534455	1087,557485	1620,05858
L2	799,241975	815,0306815	1467,4671	2126,964319
L3	1171,306276	1198,274564	2100,780563	2190,021078

Figure 4.7 Total earthquake load in X direction



	ZA	ZB	ZC	ZD
L1	598,3037165	607,9142335	1100,011931	1636,827952
L2	804,2433665	819,443674	1477,568	2128,435316
L3	1181,407126	1203,472088	2036,939272	2193,355339

Figure 4.8 Total earthquake load in Y direction

4.1.5 Lateral Forces Acting on The Storeys

Lateral forces are a type of dynamic force that acts on buildings during earthquakes, causing them to move laterally or side-to-side. These forces generate shear forces that act on the floors, walls, and other structural elements of the building, potentially leading to deformation, bending, or even collapse if they exceed the building's capacity to resist them. Therefore, designing buildings to withstand lateral forces during earthquakes is crucial for ensuring their safety and minimizing the risk of damage or loss of life during seismic events.

The magnitude of the lateral forces acting on a building during an earthquake depends on various factors, such as the earthquake's intensity, duration, and frequency content, as well as the building's size, shape, and stiffness. The lateral forces that act on the storeys of a building during an earthquake can be classified into two main types: inertial forces and shear forces.

Inertial forces are caused by the acceleration of the building during an earthquake. When the ground moves back and forth, the building tends to resist this motion and move in the opposite direction. This creates an inertial force that acts on the floors and walls of the building. The magnitude of this force is determined by the mass of the building and the acceleration of the ground motion.

Shear forces, on the other hand, are created by the lateral movement of the building during an earthquake. As the building moves laterally, it generates a shearing force between the floors and walls of the building. This force can cause the building to deform or even collapse if it is not appropriately designed to resist these forces.

As a result of the analysis performed, Table 4.4-4.7 presents detailed information regarding the horizontal forces acting on the floors for each floor class.

Table 4.4 Lateral forces acting on the storeys for ZA soil class

Storey	X Direction			Y Direction		
	L1	**L2**	**L3**	**L1**	**L2**	**L3**
10th	142.991	193.338	283.334	144.717	194.544	285.785
9th	81.474	110.158	161.437	82.454	110.864	162.830
8th	73.324	99.145	145.286	74.207	99.763	146.551
7th	65.175	88.132	129.144	65.960	88.672	130.262
6th	57.026	77.110	113.002	57.712	77.590	113.983
5th	48.876	66.097	96.860	49.475	66.509	97.694
4th	40.737	55.074	80.719	41.227	55.417	81.415
3rd	32.587	44.061	64.567	32.980	44.336	65.126
2nd	24.438	33.048	48.425	24.732	33.254	48.847
1st	16.289	22.026	32.283	16.485	22.163	32.558
Ground Fl.	8.159	11.042	16.201	8.257	11.111	16.338
Basement	434.199	1.065.806	1.413.168	441.495	1.092.696	1.447.962

Table 4.5 Lateral forces acting on the storeys for ZB soil class

Storey	X Direction			Y Direction		
	L1	**L2**	**L3**	**L1**	**L2**	**L3**
10th	145.335	197.153	289.806	147.061	198.212	291.052
9th	82.807	112.325	165.124	83.788	112.943	165.830
8th	74.531	101.097	148.610	75.413	101.646	149.247
7th	66.244	89.868	132.096	67.028	90.349	132.664
6th	57.967	78.630	115.650	58.654	79.051	116.140
5th	49.680	67.401	99.126	50.269	67.764	99.547
4th	41.404	56.261	85.691	41.894	56.467	82.954
3rd	33.117	44.934	66.077	33.509	45.169	66.362
2nd	24.840	33.696	49.563	25.134	33.882	49.769
1st	16.554	22.467	33.039	16.750	22.585	33.176
Ground Fl.	8.296	11.258	16.583	8.394	11.317	16.652
Basement	505.533	1.252.898	1655.725	514.663	1.285.524	1.697.090

Table 4.6 Lateral forces acting on the storeys for ZC soil class

Storey	X Direction			Y Direction		
	L1	**L2**	**L3**	**L1**	**L2**	**L3**
10th	263.063	354.970	508.014	266.084	357.411	492.588
9th	149.895	202.267	289.551	151.611	203.657	280.755
8th	134.900	182.040	260.592	136.450	183.292	252.678
7th	119.916	161.814	231.643	121.289	162.925	224.602
6th	104.921	141.586	202.684	106.128	142.560	196.525
5th	89.937	120.380	173.725	90.966	122.194	168.449
4th	74.942	101.133	144.776	75.805	101.828	140.372
3rd	59.958	80.907	115.817	60.644	81.462	112.296
2nd	44.963	60.680	86.857	45.483	61.097	84.220
1st	29.979	40.453	57.987	30.322	40.731	56.222
Ground Fl.	15.024	20.276	29.096	15.191	20.415	28.204
Basement	676.237	1425.346	1.522.237	683.465	1454.742	1.648.066

Table 4.7 Lateral forces acting on the storeys for ZD soil class

Storey	X Direction			Y Direction		
	L1	**L2**	**L3**	**L1**	**L2**	**L3**
10th	391.893	514.447	511.358	395.953	514.810	514.447
9th	223.288	293.150	305.163	225.602	293.356	307.007
8th	200.958	263.838	274.645	203.047	264.024	276.302
7th	178.628	234.516	244.146	180.482	234.683	245.617
6th	156.298	205.204	213.628	157.926	205.351	214.913
5th	133.969	175.892	183.110	135.361	176.010	184.218
4th	111.639	146.570	152.591	112.796	146.678	153.513
3rd	89.309	117.258	122.073	90.241	117.337	122.809
2nd	66.979	87.946	91.555	67.676	88.005	92.104
1st	44.650	58.712	61.027	45.120	57.781	61.390
Ground Fl.	22.389	29.420	30.626	22.624	29.449	30.812
Basement	405.024	838.527	985.892	452.773	938.506	1.103.170

As a result of the analysis, it was determined that the buildings with ZA Soil class were exposed to the lowest lateral forces on their floors, while the buildings with the ZD Soil class were exposed to the highest lateral forces. When the horizontal forces in the same locations and in different Soil classes are compared proportionally, the increase rate between Model-1 in ZA ground and Model-10 in ZD Soil class is calculated to be 169.6% on average.

When the analysis models with different PGA values in the same Soil class but in different locations were examined, an increase was observed in the horizontal loads affecting the floors. The models with the highest rate of increase are between Model-4 and Model-6, with an average of 99.40%.

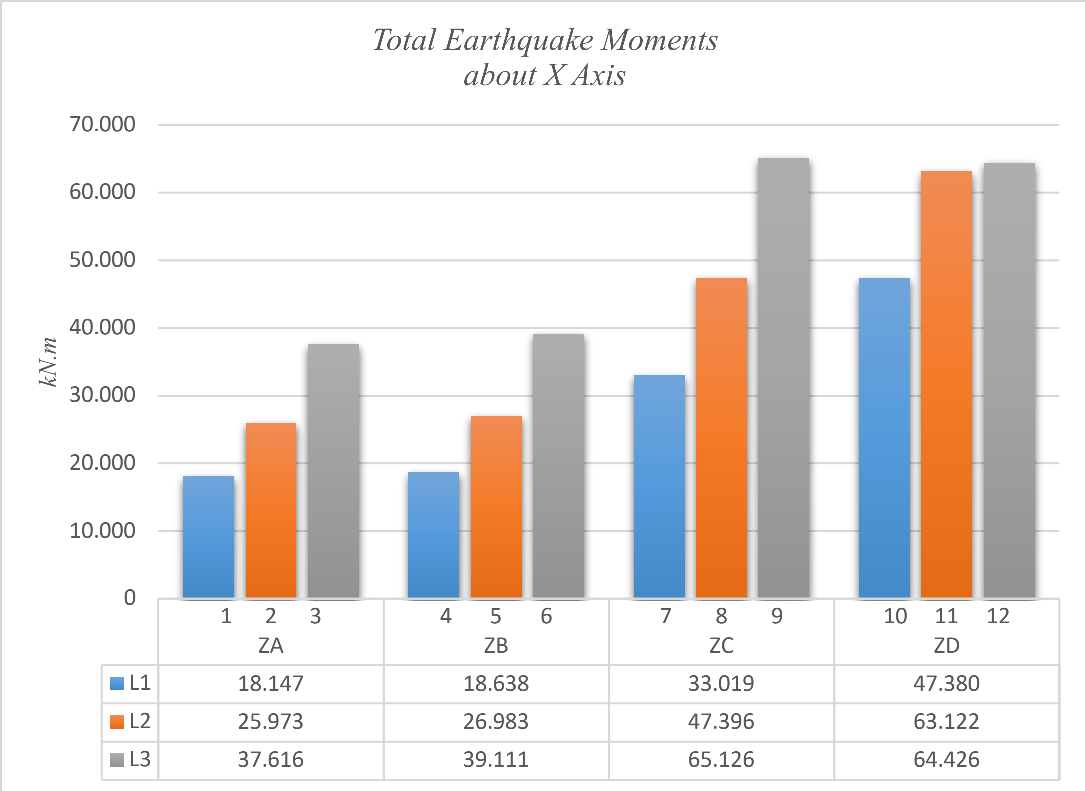
The situation in which the horizontal loads acting on the floors increase the most among all analysis models is when the floor class deteriorates and the PGA value increases. This increase averaged 257.6% between Model-1 and Model-12.

In addition, although the magnitudes of the PGA values at the locations are L3>L2>L1, respectively, the increase between the horizontal loads affecting the floors at the L2 and L1 locations was less than the L2 and L3 locations. This is because higher PGA ratios indicate a greater potential for strong ground shaking that can result in greater lateral forces during an earthquake.

In conclusion, our study highlights the importance of considering the Soil class and PGA ratio when analyzing the lateral forces acting on the floors in buildings. Buildings in areas with ZA Soil grades and lower PGA ratings are better suited to withstand lateral forces, while buildings in areas with ZD floor grades and higher PGA ratings require more attention to ensure their safety and stability.

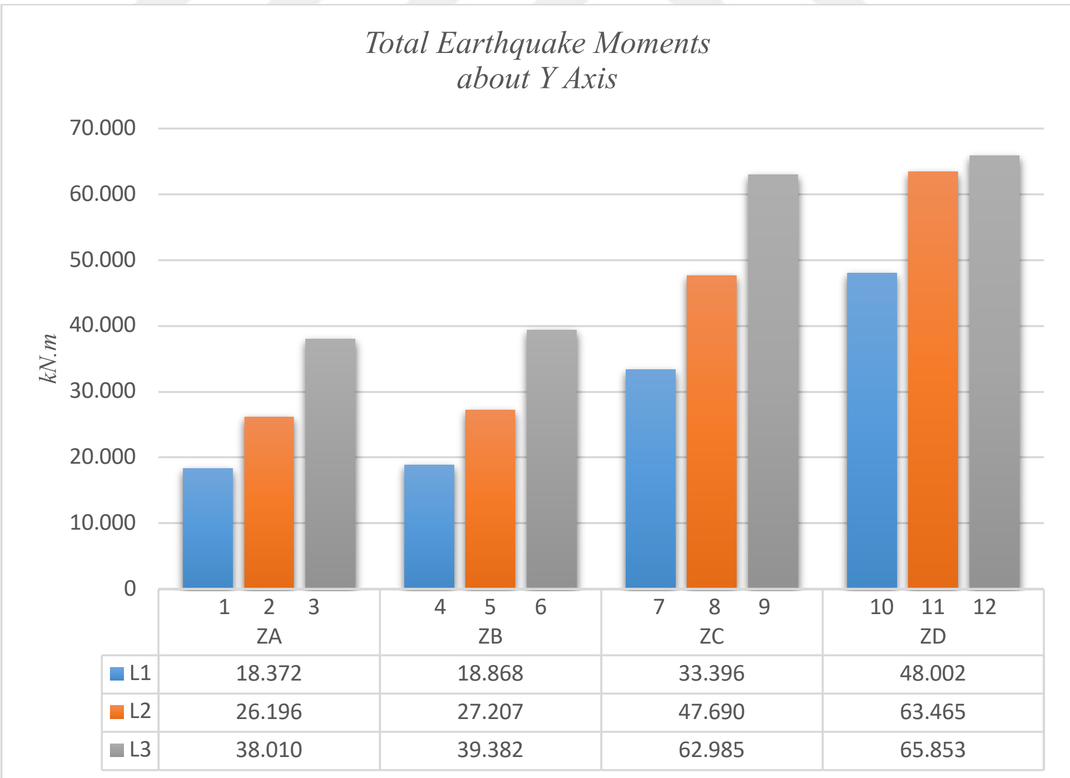
4.1.6 Earthquake Moments

The seismic moment of an earthquake is related to the amount of energy released during the earthquake, and it is not a direct measure of the shaking that a building experiences during an earthquake. However, the seismic moment can be used to estimate the magnitude of the earthquake, which can be used as a rough indicator of the severity of the earthquake shaking.



	1 2 3 ZA	4 5 6 ZB	7 8 9 ZC	10 11 12 ZD
L1	18.147	18.638	33.019	47.380
L2	25.973	26.983	47.396	63.122
L3	37.616	39.111	65.126	64.426

Figure 4.9 Total earthquake moments about X axis



	1 2 3 ZA	4 5 6 ZB	7 8 9 ZC	10 11 12 ZD
L1	18.372	18.868	33.396	48.002
L2	26.196	27.207	47.690	63.465
L3	38.010	39.382	62.985	65.853

Figure 4.10 Total earthquake moments about Y axis

4.1.7 Identifying Sections that have Changed

Buildings located in earthquake-prone areas may be exposed to different seismic loads due to varying PGA (Peak Ground Acceleration) values and local Soil classifications at different locations. These changing loads affect the building's structural system and may require changes in static design.

As the PGA value increases in certain locations along with the deterioration of the local Soil class, the earthquake-induced loads on the building are increased. Therefore, there may be an increase in the size of the columns, which are vertical structural members, to accommodate these loads.

The analysis was conducted using a PGA value of 0.140 and for various Soil classes, namely ZA, ZB, ZC, and ZD. The varying column cross-sections in Model-1, Model-4, Model-7, and Model-10 are presented in Table 4.8 The positions of the varying columns in the structure are determined as shown in Figure 4.11

Table 4.8 Changing column sections at L1 location based on soil classifications

	S13	**S16**	**S20**	**S21**
ZA	30x70	30x70	35x70	80x30
ZB	35x70	30x70	35x70	80x30
ZC	35x70	30x70	40x80	80x30
ZD	35x70	35x70	40x80	80x35

According to the analysis results, the first structural system that needs modification due to Soil class variation is column S13. Additionally, analysis conducted for Soil class ZC reveals the need to increase the cross-section of column S20. Furthermore, analysis for local Soil class ZD indicates the need to expand the cross-sections of columns S16 and S21. The cross-section enlargements increase the required amount of formwork, reinforcement, and concrete for the construction, which naturally affects the cost.

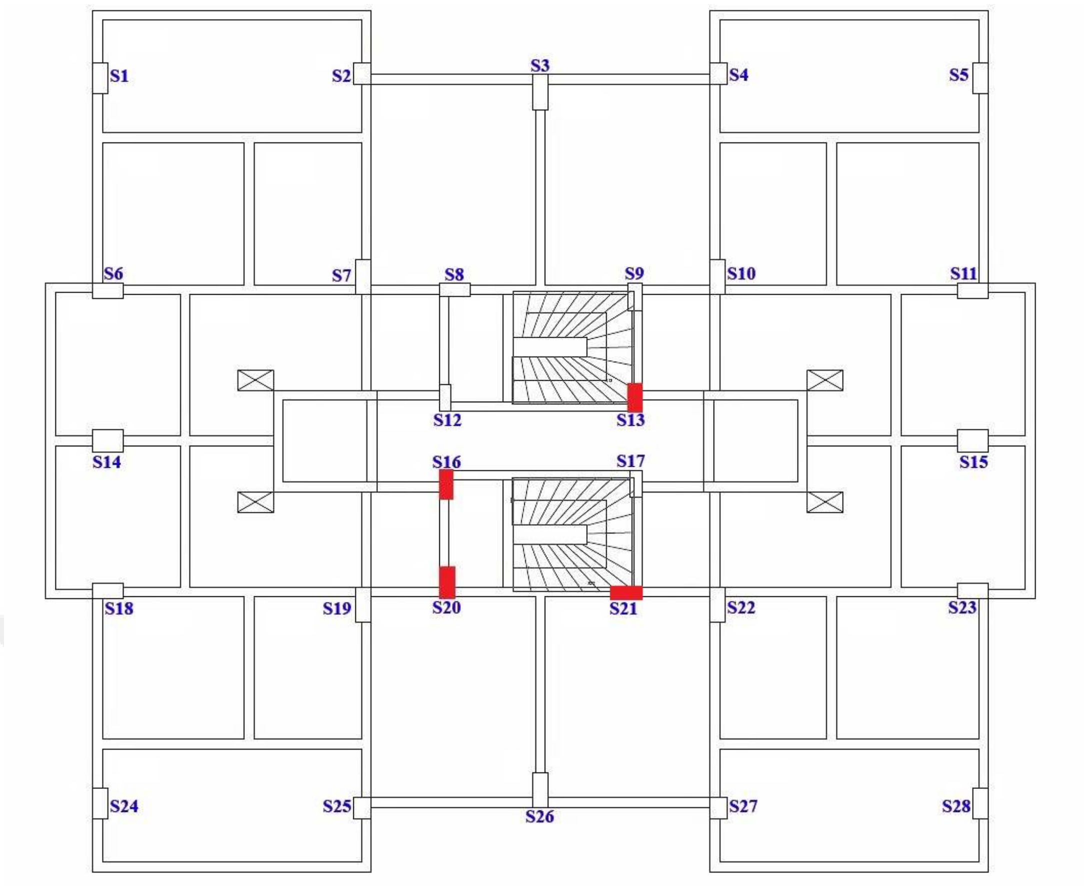


Figure 4.11 Diagram of changing columns of models belonging to L1 location

At location L2, an analysis was conducted on the local Soil classes ZA, ZB, ZC, and ZD, and a PGA value of 0.286 was determined. The varying column cross-sections in Models 2, 5, 8, and 11 are shown in Table 4.9. Additionally, the locations of the varying columns in the structure were determined as shown in Figure 4.12

Based on the analysis results, changes need to be made first to the supporting systems of columns S13 and S20 due to the variation in Soil classes in the structure. The analysis for ZC Soil class showed that no enlargement was necessary for any column cross-section. However, the analysis for ZD Soil class indicated that expansions were needed for the cross-sections of columns S16, S21, and S22.

The increased PGA value at location L2 compared to location L1 demonstrates that enlargements are needed in more supporting system cross-sections within the same local Soil class.

Table 4.9 Changing column sections at L2 location based on soil classifications

	S13	S16	S20	S21	S22
ZA	30x70	30x70	35x70	80x30	40x90
ZB	35x70	30x70	40x80	80x30	40x90
ZC	35x70	30x70	40x80	80x30	40x90
ZD	35x70	35x70	40x80	80x35	50x90

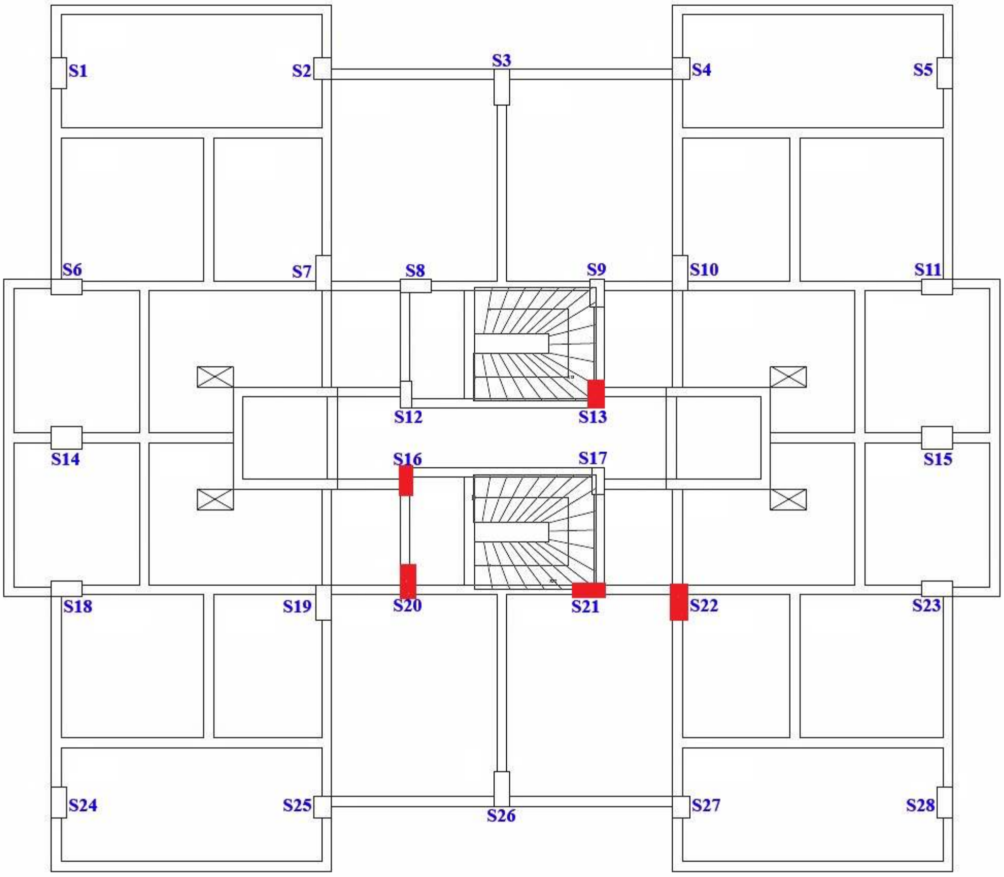


Figure 4.12 Diagram of changing columns of models belonging to L2 location

In the L3 location, analyses were performed for the local Soil classes ZA, ZB, ZC, and ZD with a PGA value of 0.384 and the changing column sections in Model-3, Model-6, Model-9, and Model-12 were shown in Table 4.10 The locations of the changing columns in the structure were also determined as shown in Figure 4. 3 According to the analysis results, changes need to be made first in the load-bearing systems of columns S7, S10, S13, and S20 due to changes in the Soil class in the structure. In the analysis of ZC Soil class, an increase in section size was observed in columns S8, S9, S10, S12, S13, S17, S19, S21, and S22. Additionally, as seen in Table 4.10, a second increase in the section sizes of columns S10 and S13 was also observed. The analysis of the ZD local Soil class indicates that only column S16 requires an increase in section size. The PGA value in the L3 location being higher than the PGA values in L1 and L2 locations has led to an increase in the number of changing columns.

The need for reinforcement is determined based on the size of the building column cross-section, the properties of the soil where the column is placed, and the risk factors of the earthquake zone.

Therefore, an increase in column cross-section size means that the reinforcement design needs to be recalculated. The reinforcement requirement is determined based on the new column dimensions, and a new reinforcement design is made. Reinforcement design is crucial to increase the earthquake resistance of structural components and ensure the safety of the building.

As a result, an increase in column cross-section due to an increase in earthquake loads can improve the earthquake resistance of the structure. However, because the reinforcement design is also affected, this cross-section enlargement should be carefully examined and calculated appropriately.

Table 4.10 Changing column sections at L3 location based on soil classifications

	S7	**S8**	**S9**	**S10**	**S12**	**S13**
ZA	40x90	80x35	35x70	40x90	30x70	30x70
ZB	50x90	80x35	35x70	45x90	30x70	35x70
ZC	50x90	80x40	40x70	50x90	35x70	40x70
ZD	50x90	80x40	40x70	50x90	35x70	40x70
	S16	**S17**	**S19**	**S20**	**S21**	**S22**
ZA	30x70	30x70	40x90	35x70	80x30	40x90
ZB	30x70	30x70	40x90	40x80	80x30	40x90
ZC	30x70	35x70	50x90	40x80	80x35	50x90
ZD	35x70	35x70	50x90	40x80	80x35	50x90

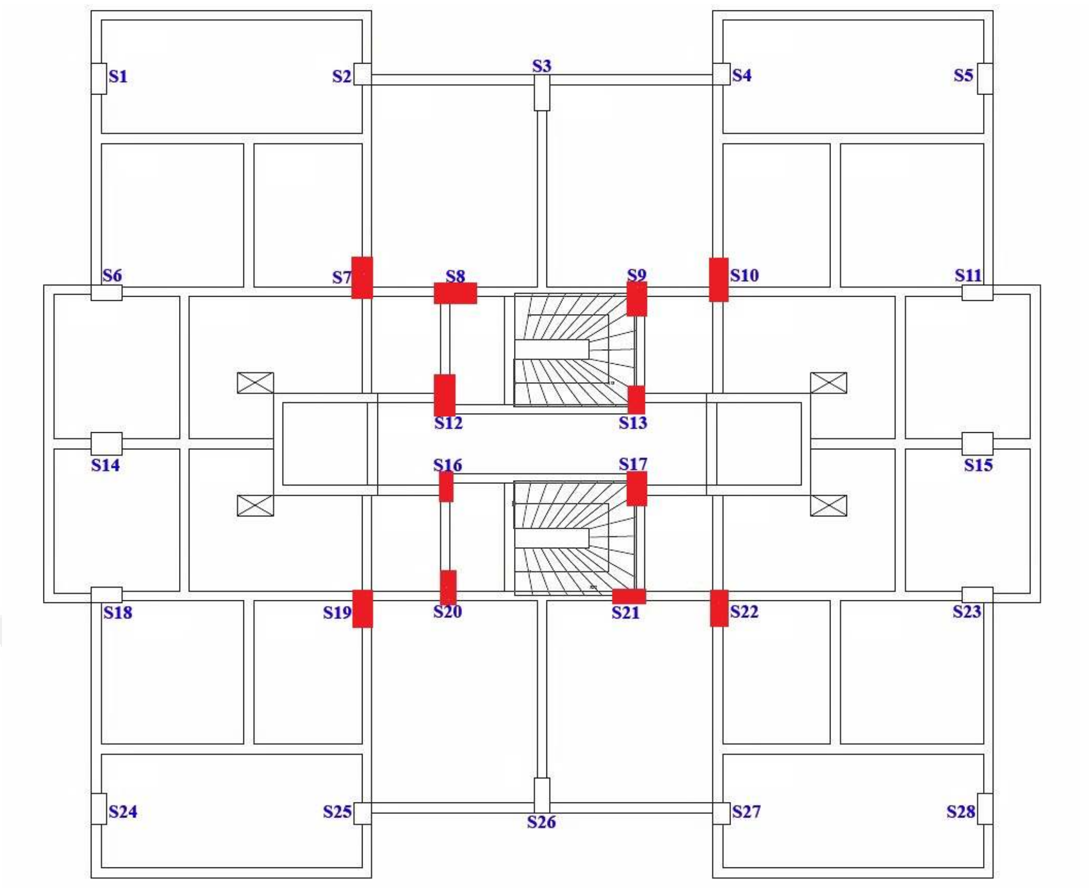


Figure 4.13 Diagram of changing columns of models belonging to L3 location

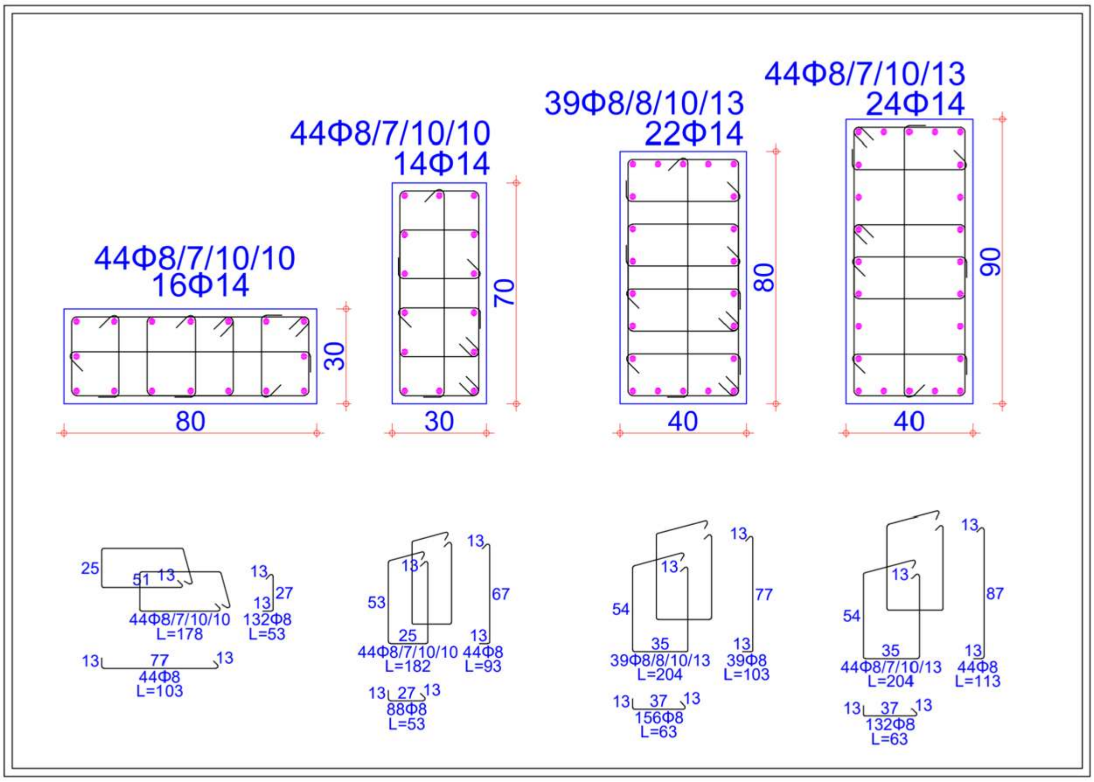


Figure 4.14 Reinforcement design for certain column types in the project

4.1.8 Mat Foundation

As a result of analyses based on changes in PGA values depending on location and worsening of local Soil classes, changes were required in the dimensions of raft foundations. According to the smallest section dimensions of Model-1, the dimensions of raft foundations in Model-12 were approximately 149% larger in volume. This increase directly caused an increase in the amount of formwork, concrete, and reinforcement.

The detailed measurements of the raft foundations are provided in the table below.

Table 4.11 Section dimensions of mat foundations

Model	Location	Soil Class	PGA	H (m)	Bx(m)	By(m)
1	L1	ZA	0.140	0.6	20.6	24.2
2	L2	ZA	0.286	0.6	20.6	24.2
3	L3	ZA	0.384	0.6	20.6	24.2
4	L1	ZB	0.140	0.9	20.6	24.2
5	L2	ZB	0.286	0.9	20.6	24.2
6	L3	ZB	0.384	0.9	20.8	24.4
7	L1	ZC	0.140	1.1	21.2	24.8
8	L2	ZC	0.286	1.1	21.6	25.0
9	L3	ZC	0.384	1.1	21.6	25.2
10	L1	ZD	0.140	1.2	21.8	25.4
11	L2	ZD	0.286	1.2	22.2	25.8
12	L3	ZD	0.384	1.3	22.2	25.8

4.1.9 Comparison of Approximate Costs

This section presents a detailed analysis of the rough construction elements of a uniform structure that was designed at three different locations. Specifically, we determined the quantities of concrete, steel, and formwork required for the structure at each location, and these values are presented in Table 4.16. To further understand the financial implications of our design, we utilized the 2023 Construction Unit Price Analysis, which was prepared by the High Council of Science under the authority of the Ministry of Environment, Urbanization, and Climate Change. By leveraging the unit prices obtained from this analysis, we were able to calculate the unit costs of the structures we designed, based on the quantities of concrete, steel, and formwork required for each location. The results of our analysis enabled us to estimate the overall costs of each structure, which is a critical aspect of the design process. By carefully assessing the costs associated with the construction of our structures, we can ensure that our designs are financially sustainable and feasible.

Overall, our analysis provides valuable insights into the feasibility of constructing similar structures in different locations. By utilizing unit prices and considering the quantities of concrete, steel, and formwork required for our design, we can make informed decisions about the construction of cost-effective and sustainable structures.

Table 4.12 The unit price of concrete [41]

Pos No	Name	Measurement Unit
151.150.1006	Pouring normal ready-mixed concrete in C 30/37 pressure strength class, gray color, produced or purchased at the concrete plant and pressed with a concrete pump (including concrete transport)	m^3
Material + Labor cost		1.292,81
25% contractor profit and overheads		323,20
1 m3 price		1.616,01

Table 4.13 The unit price of formwork [41]

Pos No	Name	Measurement Unit
151.180.1003	Making a flat surface reinforced concrete formwork with plywood	m^2
Material + Labor cost		200,46
25% contractor profit and overheads		50,87
1 m^2 price		254,33

Table 4.14 The unit price of Ø8- Ø 12 rebar [41]

Pos No	Name	Measurement Unit
151.160.1003	Ø8- Ø12 ribbed concrete steel bar, cutting, bending and repositioning of bars	ton
Material + Labor cost		15.757,54
25% contractor profit and overheads		3.939,39
1 ton price		19.696,93

Table 4.15 The unit price of Ø14- Ø 28 rebar [41]

Pos No	Name	Measurement Unit
151.160.1004	Ø 14- Ø 28 mm ribbed concrete steel bar, cutting, bending and repositioning of bars	ton
Material + Labor cost		15.558,54
25% contractor profit and overheads		3.889,64
1 ton price		19.448,18

Table 4.16 Structural material calculation

Soil Class	Location	Model	Concrete m^3	Reinforcement Tons	Formwork m^2	Total Price
ZA	L1	1	1.981.521	195.693	120.171	₺71.925.249
	L2	2	1.981.521	196.878	120.171	₺72.156.375
	L3	3	1.982.027	199.551	120.181	₺72.681.054
ZB	L1	4	2.131.077	203.934	120.440	₺73.842.679
	L2	5	2.131.077	204.113	120.441	₺73.877.599
	L3	6	2.145.439	206.885	120.570	₺74.474.244
ZC	L1	7	2.260.745	214.377	120.650	₺76.141.858
	L2	8	2.260.833	214.572	120.930	₺76.251.311
	L3	9	2.304.344	225.286	121.160	₺78.469.157
ZD	L1	10	2.345.980	221.990	120.731	₺77.784.614
	L2	11	2.377.329	230.073	120.940	₺79.464.707
	L3	12	2.434.605	235.824	121.031	₺80.701.770

CHAPTER 5
CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The study analyzed a uniform analysis model designed with four different soil classes and PGA values for three different locations. While the PGA value in the study's locations remained constant depending on the soil class, the (Fs) and (F1) values obtained from (Ss) and (S1) varied according to the soil class. Since the SDS value obtained from the multiplication of S and F values is used to determine the horizontal and vertical elastic design spectra, different horizontal and vertical design spectra were used for each analysis model. In consideration of these conditions, 12 different models were designed and structural analyses were carried out, and the results and recommendations are given below. For the local soil class in the study, ZA, ZB, ZC, and ZD were determined for all three locations. Soil bearing capacity values were determined as 60 t/m2 for ZA, 50 t/m2 for ZB, 35 t/m2 for ZC, and 30 t/m2 for ZD. The analyses were performed for 12 structures designed in response to these values. The structures investigated in the study were symmetrical, generally had the same typical plan, were considered as residential buildings, and were assumed to be affected by different soil parameters in different locations, and their static analyses were calculated. The earthquake behaviors and quantity survey values of the investigated 12 structures were compared, complying with the limit value conditions in TBDY-2018 and TS 500 regulations. As a result of the analyses, it was revealed that Model-1 created using a ZA soil class and 0.140 PGA value for Location-1 had the smallest displacement values. When looking at the soil parameters, the highest displacement value obtained from the analyses performed in all soil classes and locations was observed in Model-12 with a 0.384 PGA value in Location-3 with the lowest bearing capacity ZD local soil class.

5.2 Recommendations

Within the context of this research, the effects of local Soil class and PGA value on multi-storey reinforced concrete structures were investigated. The use of PGA values, which are highly variable in our country, in the analysis by experts before the earthquake and providing a prediction about the destructiveness after the earthquake allows to take the necessary precautions in the new buildings. In addition, the fact that the local Soil classes used in this study cause amplification in different period intervals shows that necessary precautions should be taken according to the local Soil conditions. As a result, it has been revealed that the necessity of using the design spectra to be obtained specifically for the site of the current Turkish earthquake code will allow more realistic calculation of structural analysis and performance levels.

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