EVALUATION OF ARCHITECTURAL CONSCIOUSNESS
AND
EXPLORATION OF ARCHITECTURE-BASED ISSUES
IN SEISMIC DESIGN

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ABSTRACT

EVALUATION OF ARCHITECTURAL CONSCIOUSNESS
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The task of ‘earthquake resistant design’ of buildings is generally considered as the province of engineering profession. Although there exists considerable number of publications related to seismic design (documentations, articles, theses, books, and earthquake codes), most of them are addressed to structural engineers rather than architects. However, earthquake affects whole building and all professionals involved in construction process should have their own roles and responsibilities for earthquake resistance. This thesis is about the roles and responsibilities of architects for being one of the professionals related to building construction and, particularly, the designers of them. Exposure of the level of awareness of architects related to the importance of their architectural designs having significant effects on seismic performance of buildings, and the level of general knowledge of them related to architecture-based seismic design issues is aimed.

In this thesis, firstly, terminology related to ‘earthquake’ phenomena is concisely introduced. Then, the present state of attitudes (interest, awareness and consciousness) of architectural community, architects working in the architectural offices of Ankara, towards earthquake and architecture-based seismic design issues is questioned and evaluated with a survey in the form of questionnaires. The evaluation of the results is presented with the help of statistical software called SPSS.

Finally, the architecture-based issues in seismic design are re-explored and introduced for the use of architects. Thus, general idea or basic knowledge is formed, which is inferred from the survey as being one of the ways to enhance the incorporation of architecture-based seismic design issues into architectural design process.

Keywords: Earthquake Resistant Building Design, Architectural Consciousness in Seismic Design, Architecture-Based Issues in Seismic Design, Earthquake Guidance for Architects, Earthquake Codes

ÖZ

SİSMİK TASARIMDA MİMARİ BİLİNCİN DEĞERLENDİRİLMESİ VE MİMARLIKLA İLGİLİ KONULARIN ARAŞTIRILMASI

MENDİ, H. EVGİN
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'Depreme dayanıklı yapı tasarımı' genellikle mühendisliğin uzmanlık alanı olarak düşünülür. Sismik tasarımla ilgili birçok yayın (belgeler, makaleler, tezler, kitaplar ve deprem şartnameleri) olduğu halde, bunların çoğu mimarlardan çok inşaat mühendislerine hitap etmektedir. Ancak, deprem tüm yapıyı etkiler ve yapım aşamasına dahil olan tüm meslek gruplarının, deprem dayanımında kendi rol ve sorumlulukları olmalıdır. Bu tez, bina yapım aşamasındaki mesleklerden biri ve, özellikle, tasarımcıları oldukları için, mimarların rol ve sorumlulukları ile ilgilidir. Mimarların, yapıların sismik performansı üzerinde önemli etkisi olan mimari tasarımlarının öneminden haberdar olma düzeylerinin ve mimarlıkla bağlantılı sismik tasarım konularıyla ilgili genel bilgi düzeylerinin ortaya çıkarılması hedeflenmektedir.

Bu tezde, ilk olarak, 'deprem' olgusu ile ilgili terminoloji kısaca anlatılmaktadır. Daha sonra, mimarlık camiasının, Ankara'daki mimarlık bürolarında çalışan

mimarların, depreme ve mimarlıkla ilgili sismik tasarım konularına karşı bugünkü duruşu (ilgi, haberdar olma durumu ve bilinç) sorgulanmakta ve anket şeklindeki bir alan çalışması ile değerlendirilmektedir. Sonuçların değerlendirilmesi SPSS adlı istatistiksel bilgisayar yazılımı yardımı ile sunulmaktadır.

Son olarak, mimarlıkla ilgili sismik tasarım konuları tekrar incelenmekte ve mimarların kullanımı için tanıtılmaktadır. Böylece, alan çalışmasının sonuçlarından çıkarılan, mimarlıkla bağlantılı sismik tasarım konularının mimari tasarım sürecine dahil edilme durumunu artırma yollarından biri olan, genel fikir ya da temel bilgi oluşturulmaktadır.

Anahtar Kelimeler: Depreme Dayanıklı Yapı Tasarımı, Sismik Tasarımda Mimari Bilinç, Mimarlıkla İlgili Sismik Tasarım Konuları, Mimarlar için Deprem Kaynağı, Deprem Şartnameleri

To My Parents

Semra & M. Ergin Mendi

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Special thanks to all of the participant architects, who contributed to the survey by spending their valuable time in order to fill out the forms of questionnaires and besides, to comment on the investigation.

My greatest grateful is to my family to whom I owe what I have -M. Ergin Mendi, Semra Mendi and Ş. Engin Mendi- for their support and trust in every aspect of my life, and especially my mother, Semra Mendi, for her endless love and faith in me.

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LIST OF ABBREVIATIONS

$(\Delta i)_{max}$	: Maximum storey drift
$(\Delta i)_{min}$	: Minimum storey drift
$(\Delta i)_{ort}$	: Average storey drift
Δ	: Storey drift
A	: Gross floor area
A_b	: Total area of openings
A_e	: Effective shear area
a_x, a_y	: Projection dimensions
cm	: Centimeter
d	: Separation distance
df	: Degrees of freedom
E	: Eccentricity
F	: Earthquake force
H	: Height
H_1	: Alternative hypothesis
Ho	: Null hypothesis
km	: Kilometer
L	: Length
L_x, L_y	: Plan dimensions
m	: Meter
M, M1	: Magnitude of an earthquake in Richter Scale
mm	: Millimeter
MMI	: Modified Mercalli Intensity Scale
p	: Phi-coefficient
Q	: Question number
SPSS	: Statistical Package for the Social Science
T	: Natural period of vibration

T.C. : Türkiye Cumhuriyeti

T.M.M.O.B : Türk Mühendis ve Mimar Odaları Birliği

TNT : Trinitrotoluene

UBC : Uniform Building Code

VAR : Variable number

W : Width

x^2 : Pearson chi-square value

α : Significance level at which Ho is rejected

ηbi : Torsional Irregularity Factor

ηci : Strength Irregularity Factor

ηki : Stiffness Irregularity Factor

CHAPTER 1

INTRODUCTION

1.1 Argument

Turkey is a country, which is prone to earthquakes. It is situated on one of the most effective earthquake zones of the world, namely Alp-Himalayan earthquake belt. According to the seismic zone map announced by Ministry of Public Works (T.C. Bayındırlık ve İskan Bakanlığı), approximately 95 % of Turkish geographical land is on the 1st and 2nd earthquake zones that are likely to subject earthquakes. Considering only the mentioned earthquake zones, 95 % of Turkish people, 98 % of Turkish industrial property, and 93 % of Turkish fundamental infrastructures such as bridges locate on them. Due to the destructive earthquakes, for the past 100 years, it is calculated that average of 1000 people die and 7000 buildings collapse per year (Tuna, 2000).

Thousands of people died in numerous building collapses due to many destructive earthquakes, which took place in Turkey in recent years. It is expected to face with earthquakes in the future as well, some of which may result in loss of life and property. Earthquakes are likely to turn into disasters by the collapses of built environment. Hence, it is vital to design earthquake resistant buildings in order to prevent the possible destructive physical consequences of earthquakes. As Gönençen (2000) states, what kills people is the building collapse not the earthquake, itselves. This statement emphasizes the justification of the general study topic that is 'earthquake resistant building design' or 'seismic design of buildings'.

Earthquake is a wide and a major subject to be studied that has broad research field extending from social sciences to technical sciences. When effects of earthquake on buildings are taken into account, the task of ‘earthquake resistant design’ of buildings is generally considered as the province of the engineering profession which is to be performed by structural engineers with calculations, static analyses, specifications, construction details, and so on. As earthquake affects the whole building, earthquake resistance should be shared by responsibilities of professionals and people related to building construction. Hence, architects, structural and geo-technical engineers, city planners, contractors, land owners, controllers, and other staff during the construction process have different viewpoints about their own roles and must share the responsibility for earthquake resistant design of buildings.

As being the designers of the buildings, architects give consideration to many issues such as customer demands, functions, aesthetics, environmental factors (orientation, climate, topography), standards and specifications and harmonize them with their personal ideas and concepts in the early stages of design. On the other hand, when designing on earthquake prone zones, ‘earthquake’ must be kept in mind as a design criterion on the same level with the other design issues.

According to P. L. Nervi, when an aeroplane is designed, it is not even discussed to use a form/geometry that runs to counter the basic principals of aerodynamics. For example, none of the designers of the aeroplanes choose a rectangular prism for the body of the aeroplane, as all are aware of the inappropriateness. Nervi states that when designing for earthquake prone regions, the earthquake resistant design principles for buildings are as important, critical, and vital as the principals of aerodynamics for aeroplanes (Özgen, 2002).

As Tezcan (1998) states, the experiences from the past destructive earthquakes illustrate that the causes of severely damaged or totally collapsed buildings are related, directly or indirectly, to the irregularities formed during architectural design phase. As a result, there exists a strong relationship between the architectural design and its earthquake safety. Tuna (2000) points out that earthquake resistant building design must be initiated with the architectural design phase. According to Erman (2002), "earthquake-resistant architectural principles are not the provisions that could be inserted by the structural engineer after the completion of architectural design; they should be applied to the project during the architectural design phase" (p.2).

The major concerns are the level of interest and awareness of architects about the importance of their architectural designs having significant effects on seismic performance of buildings and the level of the general knowledge of them related to the seismic design issues. As Arbabian (2000) suggests, there should be some guidance to architects in order to make them aware of the effects, which their designs may have, on the forces generated by an earthquake. Besides, Charleson (2003) states that the general lack of interest towards earthquake exists within architectural community. As a result, the critical question should be asked: "Are the architects, who are designing on earthquake prone regions in Turkey, aware of their roles and responsibilities in seismic design?" The aim of this research is to search for the answer of this question.

1.2 Scope and Objectives

This thesis focuses on two important objectives. The first objective is to evaluate the present state of attitudes (interest, awareness, and consciousness) of architectural community toward earthquake resistant building design with the help of a survey in the form of questionnaires. How architects experience and perceive seismic design with their consciousness, roles, responsibilities, awareness, and knowledge of architecture-based seismic design issues are questioned. Besides, investigation for the possible ways to enhance the incorporation of 'earthquake' as a design parameter with the more ordinary ones is searched within this study. The data is analysed with the help of statistical tools, statistical software namely 'Statistical Package for the Social Science' (SPSS).

The second objective of this thesis is to re-explore architecture-based issues related to earthquake resistant building design and to present them in a comprehensive, an understandable, and a compact format that are not based on calculations, for today's and future's architects. In order to enhance the incorporation of 'earthquake' as a design parameter with the more ordinary ones and in order to build general idea or basic knowledge, guidance or handbook, which are not too technical for architects, is formed for the use of architects. Although there exists considerable number of publications related to earthquake resistant building design (documentations, articles, theses, books, and earthquake codes), most of them are written by structural engineers for engineering professions rather than architects. In this thesis, for the consideration of structural system, reinforced concrete structural system is taken into account as being the common type used in Turkey.

1.3 Disposition

The thesis is presented in five chapters. Chapter 1, the introduction, includes the argument and the objectives of this thesis with its disposition.

Chapter 2 is the earthquake. It presents a literature survey about the phenomena. General knowledge related to earthquake is included with seismicity of world and Turkey.

Chapter 3 is the evaluation of architectural consciousness in seismic design with a case study among architects. The present state of general interest, awareness, and consciousness in 'earthquake resistant building design' within architectural community, among architects working in the architectural offices of Ankara, is examined and revealed with a survey. The results are evaluated with software, SPSS Version 13.0.

Chapter 4 is the architecture-based issues in seismic design. The architecture-based issues that influence the building's seismic performance are grouped into three categories. This is not a definite classification but it is useful to structure the issues in this way, as it makes them easy to follow. The first one is building configuration issues, which are considered as a whole. The second one is structural system (lateral resistive system) configuration issues. They explain structural system configuration in plan and in vertical. The last sub-title of Chapter 4 is the architectural non-structural components' configuration issues with architectural detailing. The Chapter 4 aims to be guidance for architects when designing on earthquake prone regions. It is the outcome of the case study (Chapter 3), as being one of the ways (preparation of guidance), in order to incorporate architecture-based seismic design issues into the architectural design process.

Chapter 5 is the conclusion. The final chapter comprises a summary of the previous assessments and the discussion of the results of the case study. It also makes some recommendations for the further studies.

CHAPTER 2

EARTHQUAKE

2.1 Definition of Earthquake

In nearly every ancient culture, earthquakes have been described as divine judgement because of their apparent randomness, lack of any visible cause, and frightening destructiveness. In many beliefs, they were thought to be the instruments of displeasure of the mythological Gods for the sinners (Coburn and Spence, 1992). Until the science of seismology became formalized, mythological earthquake legends existed within many cultures; even today, they are still in existence (Lagorio, 1990). Coburn and Spence (1992) state that it was begun to be understood what earthquakes are and what causes them, only in the twentieth century.

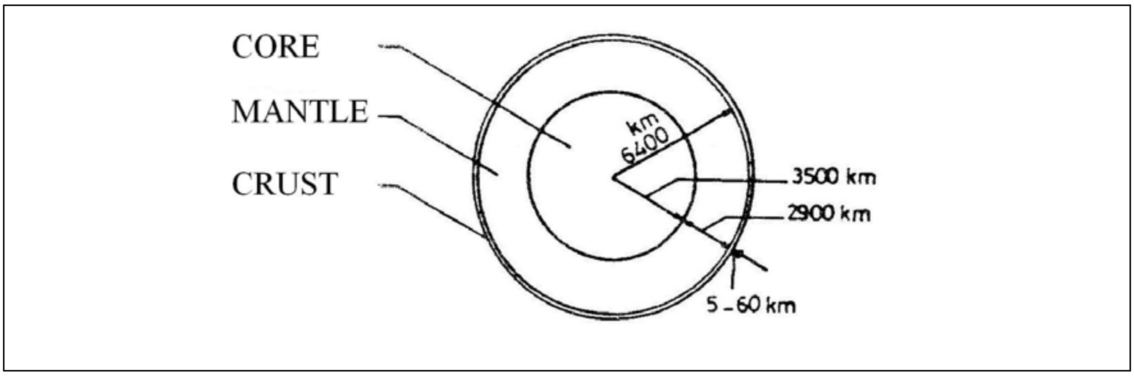

Figure 2.1: The structure of the earth (Celep and Kumbasar, 1992, p.3)

The occurrence of earthquake is related to the structure of earth **(Figure 2.1)**. The earth is composed of three main parts with different properties. These are, respectively from outer part to inner part: the crust, the mantle, and the core. The core, with a radius of 3500 km, is liquid in property. The mantle is 2900 km in thick and it has plastic (semi-molten) in property. The crust measures about 5 km in thickness under oceanic portions and 30-60 km in thickness under continental portions (Bayülke, 1989; Celep and Kumbasar, 1992).

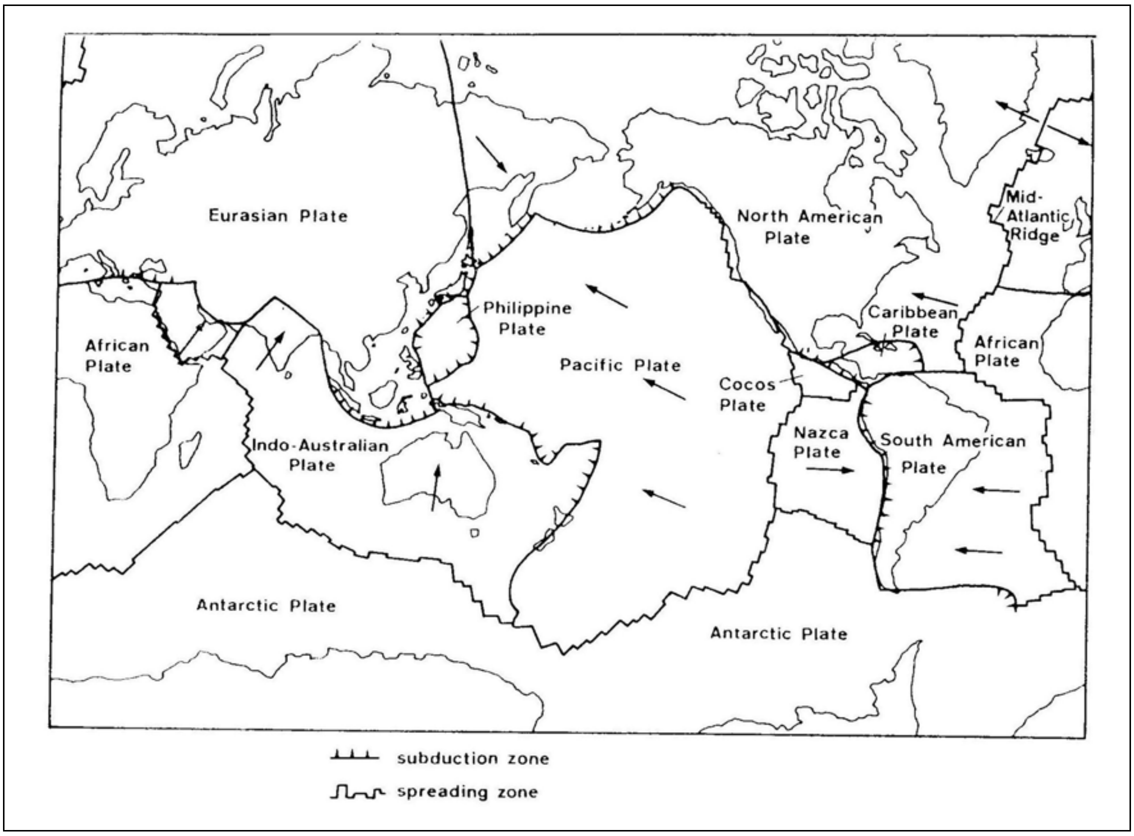

Figure 2.2: World map of tectonic plates (Wakabayashi, 1986, p.3)

Among the various theories, which have been proposed on the causes of earthquakes, the plate tectonics theory is considered as the most reliable one. According to the plate tectonics theory, the earth's crust, which is known as lithosphere, is fragmented into segment (plates) of landmasses and oceans **(Figure 2.2)** (Wakabayashi, 1986).

These several large and small hard plates are in continuous movement relative to each other with slow velocities on the semi-molten mantle. This movement is thought to be driven by the convection currents in the mantle. These plates pull apart from each other, override one another, and slide past each along their borders, which are called faults (Krinitzsky, Gould and Edinger, 1993). The motions of the plates cause stresses and deformations. Geographical formations become apparent by the movements, which take several hundred thousand years to come into being. However, sometimes, the adjacent plates cannot move because of the friction between them. They are locked into place (Lagorio, 1990). Strain energy is stored on the faults, until it exceeds the friction capacity of the plates. When accumulation of energy becomes huge enough to make the plates continue to move, rupture takes place with a sudden release of energy. Ambrose and Vergun (1985) state that "vibrations, called seismic waves, enimate from the location of the energy release and travel throughout the earth's mass. On the surface of the earth these waves cause a vibratory motion" (p.5). That vibration is what we feel as the earthquake.

2.2 Definition of Some Basic Terms

For assistance, it is necessary to explain some basic terms related to the earthquake phenomena.

2.2.1 The Focus/ Center/ Hypocenter of the Earthquake

The point where the seismic motion originates is called the focus, the center, or the hypocenter of the earthquake **(Figure 2.3)** (Wakabayashi, 1986). Architectural Institute of Japan (1970) states that the hypocenter is not limited to a point but sometimes it has considerable length or volume. The depth of the hypocenter could be several hundred kilometers, but in severe earthquakes, which cause damage to buildings, it can be less than 50 kilometers.

2.2.2 The Epifocus/ Epicenter of the Earthquake

The projection of the focus on the surface of the earth is the epifocus or the epicenter of the earthquake **(Figure 2.3)**. The distance from the focus to the point of observed ground motion, the epicenter, is called the focal distance/depth or the epicentral distance (Wakabayashi, 1986).

2.2.3 The Focal Region

Seismic waves propagate from the focus through a limited region of the surrounding earth body. That is called the focal region. The size of the focal region is proportional to the strength of the earthquake (Wakabayashi, 1986).

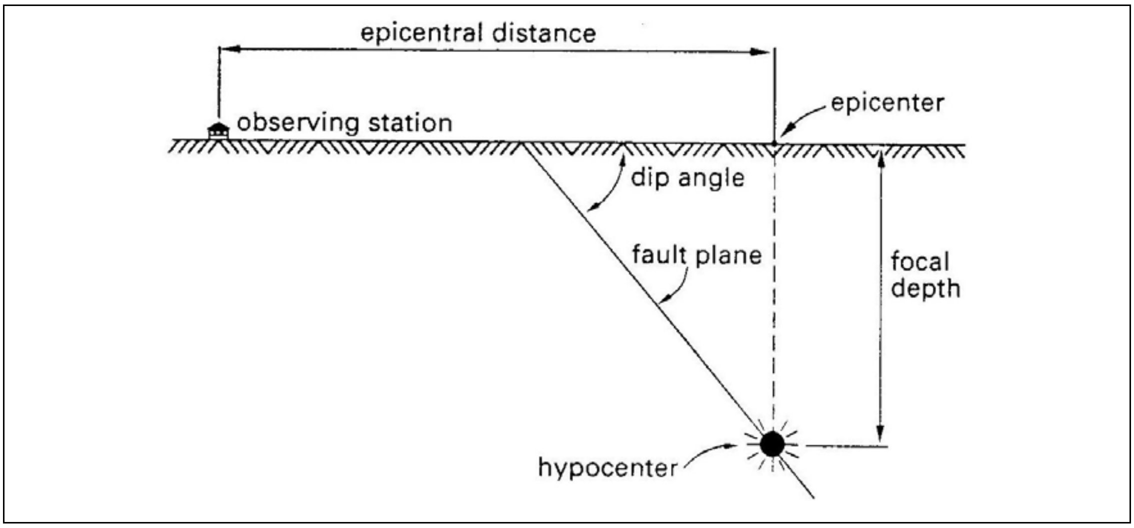

Figure 2.3: Earthquake terminology (Lindeburg and Baradar, 2001, p.2)

2.3 Types of Earthquakes

Earthquakes can be classified into four groups with regard to their properties. These are earthquakes according to the focal depth, earthquakes according to the distance from the recording device, earthquakes according to the magnitude, and earthquakes according to the origin.

2.3.1 According to the Focal Depth of the Earthquakes

The earthquakes can be classified into three groups depending on their focal depths (Lindeburg and Baradar, 2001).

- Shallow earthquakes: The focal depth is less than 60 km.
- Intermediate earthquakes: The focal depth ranges from 60 to 300 km.
- Deep earthquakes: The focal depth is up to 700 km.

In Turkey, generally shallow earthquakes with a focal depth of 0-30 km occur (Özmen, 2002).

2.3.2 According to the Distance from the Recoding Device

According to the distances from the recording devices, earthquakes can be classified into four groups (Özmen, 2002).

- Local Earthquake: The distance is less than 100 km.
- Proximity Earthquake: The distance is between 100-1000 km.
- Regional Earthquake: The distance is between 1000-5000 km.
- Distant Earthquake: The distance is more than 5000 km.

2.3.3 According to the Magnitude of the Earthquake

Six groups of earthquakes can be classified according to their magnitudes **(Section 2.6)** measured by Richter scale (Özmen, 2002).

- Very Strong Earthquake: $M>8.0$
- Strong Earthquake: $7.0<M<8.0$
- Medium Earthquake: $5.0<M<7.0$
- Small Earthquake: $3.0<M<5.0$
- Micro Earthquake: $1.0<M<3.0$
- Ultra- Micro Earthquake: $M<1.0$

Wakabayashi (1986) states that earthquakes of larger magnitude occur less frequently than those of smaller magnitude.

2.3.4 According to the Origin

According to the origin, the earthquakes can be classified into four groups (Özmen, 2002).

- Tectonic Earthquake: They have come into being because of movements of plates. Bayülke (1989) states that 90 % of the world's earthquakes belong to this group. Almost all of the destructive earthquakes, which have occurred in Turkey, are tectonic earthquakes.
- Volcanic Earthquake: They have come into being because of volcanic activities.
- Subsidence Earthquake: They have come into being because of collapses of caves and mines. Landslides are also the causes of subsidence earthquakes.
- Non-natural Earthquake: They have come into being because of non-natural events such as nuclear explosions.

The larger magnitude of the volcanic, subsidence, and non-natural earthquakes occur less frequently than the ones for tectonic earthquakes (Celep and Kumbasar, 1992).

2.4 Seismic Faults

Lindeburg (2001) describes a fault as "a fracture in the earth's crust along which two blocks slip relative to each other" (p.5). It is appropriate to consider faults as the results of earthquakes rather than the causes of them (Bayülke, 1989; Celep and Kumbasar, 1992). The displacement along the fault, the slippage with respect to another, during an earthquake can be in any direction: vertical, horizontal, or a combination of two **(Figure 2.4)** (Lagorio, 1990).

Krinitzsky, Gould, and Edinger (1993) state that all faults do not produce earthquakes. Faults having potentials for generating earthquakes are active faults. They have undergone deformation for the past several hundred thousand years and the deformation will continue in the future. Since earthquakes often occur at active faults, when designing an important structure such as a nuclear power plant, the distance from a nearby active fault to the building site is to be taken into account (Wakabayashi, 1986).

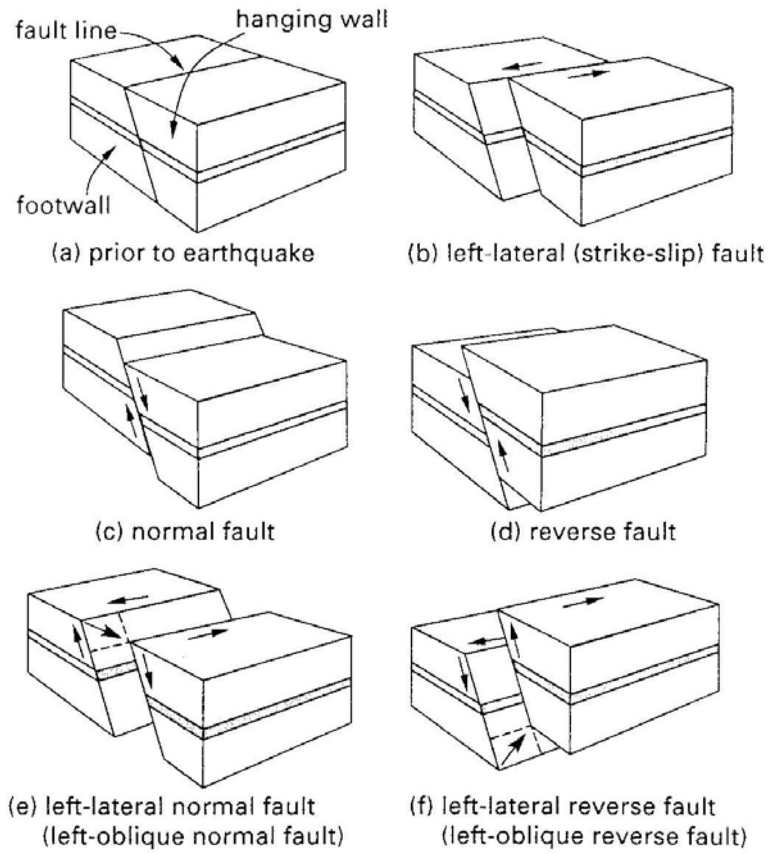

Figure 2.4: Types of faults (Lindeburg and Baradar, 2001, p.5)

2.5 Seismic Waves

There exist two types of seismic waves: the body wave and the surface wave. The body waves, P wave (primary, longitudinal or compressive) and S wave (secondary, transverse or shear), radiate from the hypocenter through the interior of the earth. The P wave, which reaches the surface first, propagates in the same direction as its own vibration. The S wave, which travels more slowly than the P wave, propagates in a direction perpendicular to its vibration causing the majority of damage to structures (Wakabayashi, 1986). Wakabayashi (1986) states that the waves transmitted along the earth's surface are called the surface waves. They are detected more often in shallow earthquakes and they arrive after P and S waves. The two kinds of surface waves are L wave (love) and R wave (rayleigh). The L wave vibrates in a plane parallel to the earth's surface and perpendicular to the direction of wave propagation. The R wave vibrates in a plane perpendicular to the earth's surface and exhibits an elliptic movement **(Figure 2.5)**.

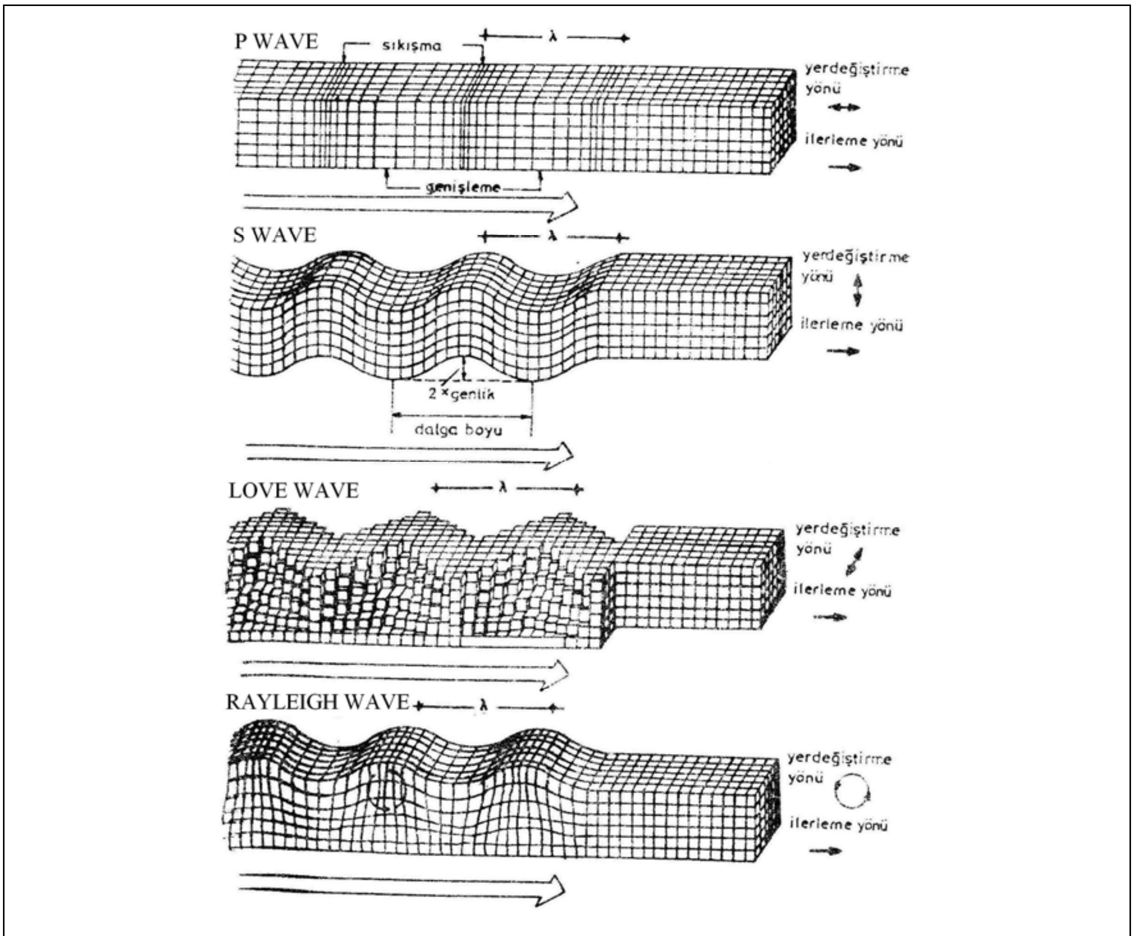

Figure 2.5: Types of seismic waves (Celep and Kumbasar, 1992, p.22)

As the earth's structure is not homogeneous and the various layers having different characteristics are near the earth's surface, various kinds of waves are produced by reflections and refractions through the various layers of earth. Even the wave motion near the hypocenter is very simple; it becomes complicated at a point. Because various kinds of surface waves are produced after the body waves reach to the earth's surface (Architectural Institute of Japan, 1970).

2.6 Magnitude

In order to give a complete picture of an earthquake, it is necessary to use two measures: the magnitude and the intensity. When they are used together, they give the answers of these questions: Where the seismic event takes place, how large it is and what its impacts are on the built environment (Lagorio, 1990).

Wakabayashi (1986) describes magnitude as a quantitative measure of the size of an earthquake, which is closely related to the amount of energy released from the hypocenter. A number of magnitude scales are in use. The most extensively used magnitude scale is the Richter Magnitude Scale developed by Professor Charles Richter in 1935 (Lagorio, 1990) and denoted as M or Ml (Dowrick, 1987). Richter magnitude is expressed in whole numbers and decimals. As the Richter scale is a logarithmic scale, the significance goes up rapidly. Lagorio (1990) states that "every upward step of one magnitude unit represents the multiplication of the recorded amplitude by a factor of 10" (p.14). For example, a Richter magnitude of 4 records 10 times the amplitude of a 'Richter 5', and a 'Richter 6' records 100 times much energy than that of the 'Richter 4'. Although the Richter Magnitude Scale is an open-ended scale with no upper limit, the largest known earthquakes have approached to a Richter 9.0 (Lagorio, 1990).

It is important to notice that earthquakes of similar Richter magnitudes may differ greatly from each other in the physical effects produced on the built environment. Because the destructive effects of earthquakes with similar magnitudes depend on the geological characteristics, through which seismic waves travel, and the depth of the earthquake (Lagorio, 1990). A shallow-focused earthquake will be more destructive than a deep-focused one even the magnitudes of them are similar (Bayülke, 1989).

The magnitudes of earthquakes can be grouped into four categories. These are:
Magnitudes less than 4.5: Magnitude 4.5 represents an energy release of about 10 tons TNT being exploded underground. Although earthquakes with magnitudes 4.5 or less may be quite widely felt by people, they have little potential to cause damage. For earthquakes of magnitude 3.0 or 2.0 become difficult for seismographs to detect unless they occur close to the earth's surface (Coburn and Spence, 1992).

Magnitudes less than 4.5 to 5.5 - local earthquakes: Magnitude 5.5 represents an energy release of about 1000 tons TNT being exploded underground. Earthquakes with magnitudes up to about 5.5 can occur almost anywhere in the world as being the level of energy release that is possible in normal non-tectonic geological processes. For earthquakes of magnitude 5.0 to 5.5 may cause damage if they are shallow earthquakes (Coburn and Spence, 1992).

Magnitudes 6.0 to 7.0 - large magnitude earthquakes: Magnitude 6.0 represents an energy release of about 6000 tons TNT being exploded underground. A magnitude of 6.3 is generally taken as being about equivalent to an atomic bomb being exploded underground. If large magnitude earthquakes occur close to earth's surface, they may cause severe damage of buildings. However, some of these are associated with tectonic processes at depth and may be relatively harmless to people on the earth's surface (Coburn and Spence, 1992).

Magnitudes 7.0 to 8.9 - great earthquakes: Magnitude 8.0 represents an energy release more than of about 400 atomic bomb being exploded underground, almost as much as a hydrogen bomb. The largest earthquake yet recorded has the magnitude of 8.9. They have great destructive potential to the very large areas with strong intensities (Coburn and Spence, 1992).

2.7 Intensity

Dowrick (1987) describes intensity as “a qualitative or quantitative measure of the severity of seismic ground motion at a specific site” (p.5). Intensity is based on damage and other observed effects on people, buildings, and other features (Lindeburg and Baradar, 2001).

An intensity scale is the scale of ground-motion intensity as determined by human feelings and by the effects of ground motion on structures and on living things (Wakabayashi, 1986). Lindeburg and Baradar (2001) state that an intensity scale consists of a series of responses, such as people awakening, furniture replacement, and chimneys being damaged.

Although a number of intensity scales have been developed, the most widely used is the Modified Mercalli Intensity Scale (MMI), developed in 1931 by the American seismologists Harry Wood and Frank Neumann (Lindeburg and Baradar, 2001). The Modified Mercalli Intensity Scale consists of 12 increasing levels of intensity expressed as roman numerals, ranging from MM-I to MM-XII. While the lower numbers of the intensity scale are based on the manner in which the earthquake is felt by people, the higher numbers are based on observed structural damage (Lindeburg and Baradar, 2001).

The difference in grading system avoids confusion between two scales: the magnitude scale with arabic numerals and the intensity scale with roman numerals. Another difference between two scales is that while the Richter scale is open-ended, the modified Mercalli scale is a close-ended measuring with maximum intensity of XII (Lagorio, 1990). The relationship between two of the scales is shown in **Table 2.1**.

Table 2.1: The relationship between the intensity and the magnitude of an earthquake (Tuna, 2000, p.16)

Intensity	IV	V	VI	VII	VIII	IX	X	XI	XII
Magnitude	4	4.5	5.1	5.6	6.2	6.6	7.3	7.8	8.4

As the intensity is not the expression of the direct record of seismographs, the trained observers assign the intensity level according to the field observations of destruction in accordance with the descriptions of damage listed **(Table 2.2)** in the Modified Mercalli Scale (Lagorio, 1990).

Table 2.2: Modified Mercalli Intensity Scale (Lindeburg and Baradar, 2001, p.9-10)

Intensity	Observed effects of earthquake
I (Not noticeable)	Not felt except by very few under especially favourable conditions.
II (Scarcely noticeable- Very slight)	Felt only by a few persons at rest, especially by those on the upper floors of buildings. Delicately suspended objects may swing.
III (Weak)	Felt quite noticeably by persons indoors, especially in the upper floors of buildings. Many people do not recognize it as an earthquake. Standing vehicles may rock slightly. Vibrations similar to the passing a truck. Duration estimated.
IV (Largely observed)	During a day, felt indoors by many, outdoors by a few. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing vehicles may rock noticeably.

Table 2.2 (continued)

V (Strong)	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI (Slight damage)	Felt by all, many frightened. Some heavy furniture moved. A few instances of all fallen plaster. Damage slight.
VII (Damage to buildings)	Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built structures. Some chimneys broken.
VIII (Destruction of buildings)	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings, with partial collapse. Damage great in poorly built structures. Fallen chimneys, factory stacks, columns, monument, and walls. Heavy furniture overturned.
IX (General damage to buildings)	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
X (General destruction to buildings	Some well-built wooden structures destroyed; most masonry and frame structures with foundations destructed. Rails bent.
XI (Catastrophe)	Few, if any, masonry structures remain standing. Bridges destroyed. Rails bent greatly.
XII (Landscape changes)	Damage total. Lines of sight and level are distorted. Objects thrown into air.

2.8 Seismicity of the World

The geographical distribution of earthquake activity in the earth's crust is shown in **Figure 2.6**. According to Coburn and Spence (1992), three features are dominant in terms of the concentration of seismic activity in particular zones:

- There is a line of earthquakes through the middle of each of the great oceans, which is called mid-ocean ridges.
- There is a series of island arcs running down the western side of the Pacific Ocean from Alaska (in the north) to New Zealand (in the south). These are the Aleutian Islands, Japan, the Philippines, the islands of Southeast Asia and the South Pacific. Another island arc runs through Caribbean and Greece.
- Two prominent earthquake belts are associated at continental margin. First one is Pacific earthquake belt, on the eastern coasts of the Pacific Ocean stretching along America; the second one is trans-Asiatic zone namely Alp-Himalayan earthquake belt (Coburn and Spence, 1992).

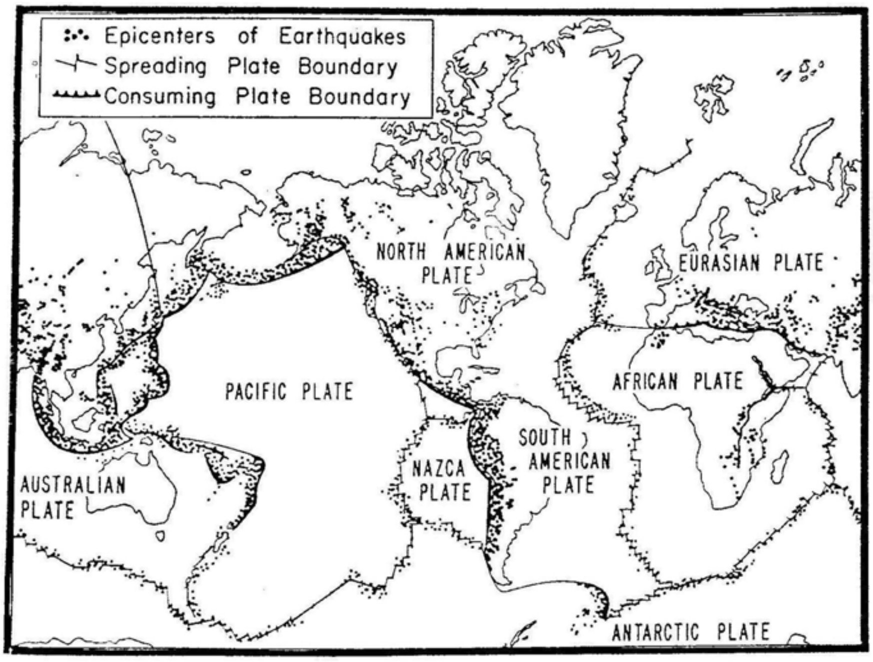

Figure 2.6: Seismicity of the World (Lagorio, 1990, p.7)

95 % of earthquakes of the world occur on these two main earthquake belts: Pacific earthquake belt and Alp-Himalayan earthquake belt (Erman, 2002). Erman (2002) further states that 80 % of all the earthquakes occur on the coasts of the Pacific Ocean. China, Japan, the west side of the America, the west coast of Canada, Alaska, countries on the west coast of the south America continent, New Zealand, Indonesia, the Philippines are the places where destructive earthquakes frequently occur (Bayülke, 1989). In addition to this, Alp-Himalayan earthquake belt, where 15 % of all the earthquakes occur, according to Erman (2002), contains all Mediterranean countries: Iran, Caucasus, and Turkey (Celep and Kumbasar, 1992).

Coburn and Spence (1992) states that “elsewhere, earthquakes do occur, but the pattern of activity is less dense, and the magnitudes are generally smaller” (p.13).

2.9 Seismicity of Turkey

As Turkey is situated on Alp-Himalayan earthquake belt, one of the prominent earthquake belts of the world, Turkey has been living with earthquake risk for many years. According to the probability of the occurrence of earthquakes, Turkey is separated into 17 earthquake faults (Gülkan, Koçyiğit, Yücemen, Doyuran and Başöz, 1993). However, Bayülke states that the most important faults are North Anatolian Fault, West Anatolian Horst- Graben System, and East Anatolian Fault. The most risky one is the North Anatolian Fault (Bayülke, 1989).

The North Anatolian Fault having a length of 1300 km runs from Karlıova in the east to Saros Gulf in the west (Erman, 2002) (**Figure 2.7**). Erman states that 35000 earthquakes occurred on the North Anatolian Fault. Some of the destructive ones occurred on the North Anatolian Fault are: 1939 Erzincan (M=8.0 and 32962 loss of life), 1942 Erbaa (M=7.0 and 3000 loss of life), 1944 Bolu (M=7.4 and 3959 loss of life), 1966 Varto (M=6.9 and 2394 loss of life), 1967 Adapazarı (M=7.2 and 89 loss of life), 1976 Çaldıran (M=7.2 and 3840 loss of life), 1983 Erzurum-Kars (M=6.8 and 1155 loss of life), 1992 Erzincan (M=6.1 and 801 loss of life), 1999 Marmara

(M=7.4 and 35000 loss of life) (Bayülke, 1989; Celep and Kumbasar, 1992; Erman, 2002). An earthquake with a magnitude greater than 7.0 is expected to occur on the unsnapped parts of the North Anatolian Fault. These are the region from Marmara Sea to Saros on the west and the region between Erzincan and Karlıova, with a length of nearly 75 km (Erman, 2002).

The second most important earthquake fault is the West Anatolian Horst- Graben System. It runs through Aegean region stretching from Ayvalık, Dikili, İzmir, Çeşme, Aydın, and Great Menderes River to Denizli, Isparta, and Akşehir. Some of the destructive earthquakes occurred on the West Anatolian Horst- Graben System are: 1928 Torbalı (M=7.0 and 50 loss of life), 1944 Ayvalık-Dikili (M=7.0 and 27 loss of life), 1949 İzmir-Karaburun (M=7.0 and 2 loss of life), 1955 Söke-Aydın (M=7 and 23 loss of life), 1969 Alaşehir (M=6.6 and 41 loss of life), 1970 Gediz (M=7.2 and 1086 loss of life), 1976 Çaldıran-Muradiye (M=7.2 and 3840 loss of life) (Bayülke, 1989; Celep and Kumbasar, 1992).

The third most important earthquake fault is the East Anatolian Fault (**Figure 2.7**). It has a length of 400 km running from Karlıova to Adana (Erman, 2002). Erman (2002) states that two important faults, the North Anatolian Fault and the East Anatolian Fault, intersect at Karlıova. No destructive earthquake took place on the East Anatolian Fault until the last period of republic. The important earthquakes occurred on the East Anatolian Fault are: 1964 Malatya (M=6.0 and 8 loss of life), 1971 Bingöl (M=6.7 and 878 loss of life), and 1975 Lice (M=6.7 and 2385 loss of life) (Bayülke, 1989; Celep and Kumbasar, 1992).

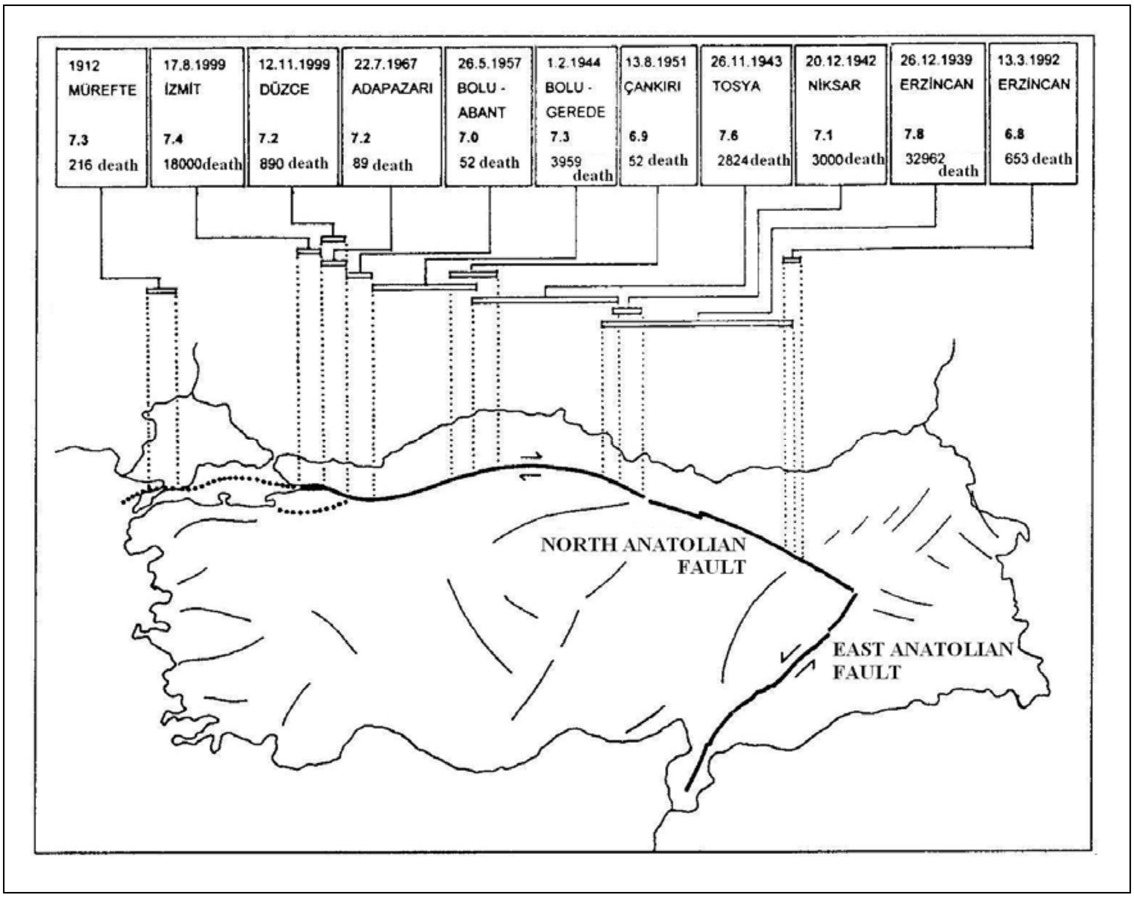

Figure 2.7: North Anatolian Fault and East Anatolian Fault (Erman, 2002, p.28)

Turkey is separated into five earthquake zones in terms of the earthquake risk capacity (**Figure 2.8**). 1st and 2nd ones are the most risky zones on which great and destructive earthquakes are expected to occur. On 3rd and 4th zones, moderate earthquakes are expected to occur and these zones are likely to be affected from the great earthquakes of 1st and 2nd zones. Earthquake zone with no risk is the 5th zone. Here, either no earthquake is expected to occur or only smaller earthquakes occur. Moreover, earthquakes of the other zones do not affect 5th earthquake zone (Bayülke, 1989). Only Ankara and Konya from middle Anatolia are on the 4th earthquake zone. Karaman and south part of Aksaray are on the 5th earthquake zone. Despite the existence of 4th and 5th earthquake zones in Turkey, Turkey is accepted to be the 2nd degree earthquake zone in the world. It is assumed that no earthquake with greater magnitude than 8.0 will occur (Erman, 2002).

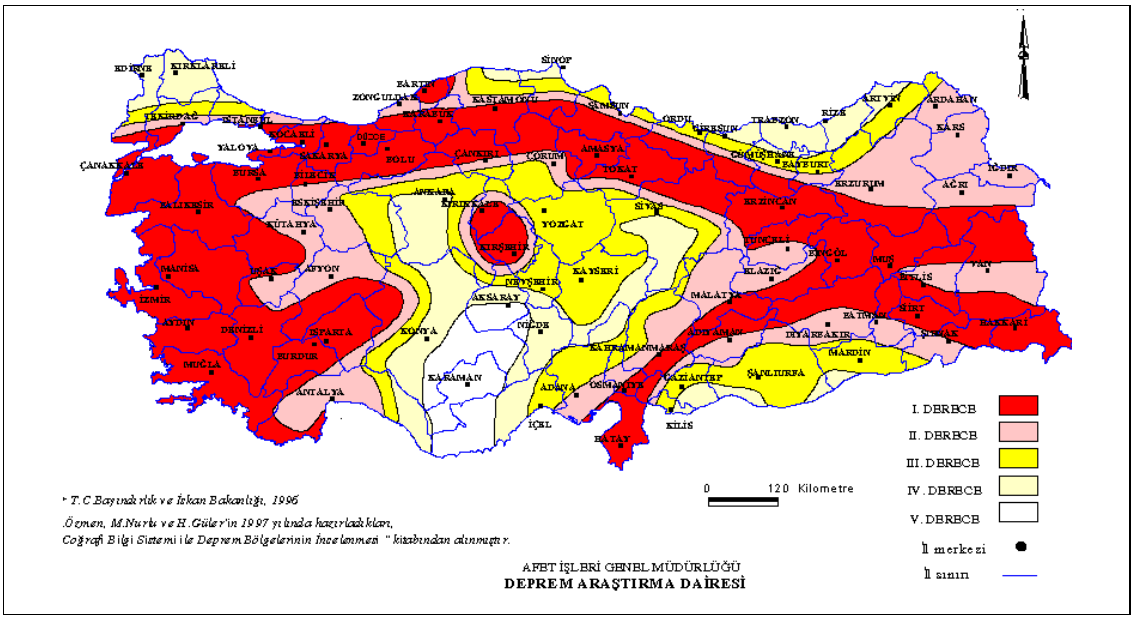

Figure 2.8: Earthquake Zones in Turkey (www.deprem.gov.tr)

CHAPTER 3

ARCHITECTURAL CONSCIOUSNESS IN SEISMIC DESIGN: A CASE STUDY AMONG ARCHITECTS

The aim of this research is to examine and to expose the present state of general interest, awareness, and consciousness in 'earthquake' or specifically 'earthquake resistant building design' within architectural community, among architects working in the architectural offices of Ankara in 2005, in order to search the possible ways of incorporating architecture-based seismic design issues into the architectural design process. The case study is organized into five sections. First, the roles and the responsibilities of architects in seismic design and the critical importance of the architecture-based seismic design issues are defined and the importance of the topic for survey (a research approach) is discussed. Then, main research problem and hypotheses are explained. In the following section, the method to be used for the empirical research is introduced and its results are analysed. Final part is the discussion part.

3.1 Introduction

The overall form and configuration of the building, the choice of structural system, the configuration of structural elements, the design of non-structural components and the construction techniques are the architectural aspects that affect the earthquake performance of buildings (Arbabian, 2000). The significant importance of the effects of the architectural aspects on the seismic performance of the buildings should not be neglected.

Hence, when architects are designing buildings, they should take the architecture-based issues related to seismic design into consideration. However, the major issue of concern is the level of interest, awareness and the general knowledge and design skills related to seismic design that should be expected from architects during the architectural design process (Ambrose and Vergun, 1985). In order to understand and evaluate the level of consciousness, a survey (a type of research design) is to be performed. It is necessary to question whether architects are aware of their roles and responsibilities in seismic design or not.

3.2 Aim and Objectives

The main research problem is the exploration of the present state of attitudes (interest, awareness and consciousness) of architects, who are working in architectural design offices, toward earthquake and architecture-based issues related to earthquake resistant building design. This study focused on analysing two important issues. One issue is to explore how architects experience and perceive seismic design: roles, responsibilities, awareness, and knowledge of architecture-based seismic design issues. Second issue is to investigate the possible ways to enhance the incorporation of 'earthquake' as a design parameter with the more ordinary ones. This case study hopes to contribute the field of seismic design in an architectural point of view.

The following five hypotheses are designed in order to test the relevant issues:

Arnold (1989) states that the architectural design decisions play a major role in determining the seismic performance of the building. The size, the dimensions in plan and vertical, the overall form and geometry, the choice of structural system, and the placement of the center of mass and rigidity are the most important factors that affect its seismic performance. Those are decided by the architect, before the structural engineer makes his contribution (Tezcan, 1998). On the other hand, selection, design, and configuration of the non-structural elements such as the type and the distribution of partition walls, are to be controlled by architect without reference to the structural engineer. Lagorio (1990) points out that damage of the architectural elements, during an earthquake could cause major economic losses even with minor structural damage. He notes that the damage in 1964 Alaska Earthquake accounted for up to 65 - 70 % of a building's replacement cost. Therefore, it is evident that architects should be familiar with the basic rules of earthquake resistant building design, so that they can incorporate the rules in their building solution already from the first sketch (Slak and Kilar, 2003). Accordingly, the main hypothesis is designed:

Hypothesis 1 (Ho_1): Architects, who are aware of the importance of the architectural design and its related issues on seismic performance of the building, are more conscious about their roles and responsibilities in earthquake resistant building design.

Ambrose and Vergun (1985) state that the task of 'earthquake resistant design' of buildings is usually performed by structural engineers, who produce the computations, specifications, and construction details. However, the responsibility for seismic design extends beyond the structural engineers. Slak and Kilar (2003) point out that "no static analysis could assure a good dissipation of energy and favourable distribution of damage in irregular buildings, such as structures with large asymmetry or soft storeys" (p.2). Therefore, the awareness of architects about the issue should be investigated with a related hypothesis:

Hypothesis 2 (Ho_2): Architects consider earthquake resistant building design as the province of the engineering profession, which is regarded as the responsibility of structural engineers.

It is essential to discuss the necessity of consideration of earthquake and architecture-based issues related to seismic design as a design criterion. The present attitude of architects towards the issue should be questioned. Thus, third hypothesis is formed:

Hypothesis 3 (Ho_3): Architects do not give adequate consideration to ‘earthquake’ as a design criterion, when it is compared with the more ordinary ones.

Slak and Kilar (2003) point out that the earthquake codes are much more suited to the needs of structural engineers rather than the needs of architects. The 1998 Turkish Earthquake Code is difficult to understand even for structural engineers, so architects generally are not interested in, because it was not prepared for them. It is too sophisticated and technical for practical use (Tezcan, 1998). Arbabian (2000) states that in order to make architects be aware of the effect, which architectural design may have on earthquake forces, it would be advisable to provide some guidance to architects. Consequently, a relevant hypothesis is developed:

Hypothesis 4 (Ho_4): 1998 Turkish Earthquake Code is not serviceable for the use of architects, therefore some guidance such as regulations for architects needs to be provided.

Sözen (1979) emphasizes the importance of mutual coordination between the architect and structural engineer working in a seismic area (Arnold, 1989). According to Sözen (1979), “in resistance to gravity loads, architectural and structural decisions may be made by independently of each other. But in resistance related to earthquake effects, separating the engineer from the architect is a formula for disaster” (p.170). Hence, the last hypothesis is designed:

Hypothesis 5 (Ho_5): There exists a lack of communication between the architect and structural engineer during the architectural design phase, as architects consider seismic design is performed by structural engineer’s contributions as an afterthought.

3.3 Methodology

The study is based on the data of an empirical research about the architectural consciousness in seismic design. The study conducted qualitative (based on comments) and quantitative (based on percentages) analyses to test the above mentioned hypotheses. The main concern is to point out the importance of seismic design within architectural community from the perspective of architects, who are experienced in designing.

3.3.1 Setting of the Research and Sample Group

The sample group mainly contains the architects who are working in the architectural design offices of Ankara, in 2005. There exist 430 architectural offices enrolled to the Chamber of Architects of Ankara (T.M.M.O.B Mimarlar Odası Genel Merkezi, Ankara), on May 2005. As, according to the Chamber, it is not ethical to clarify all the names and relevant information (telephone numbers and addresses) of the architectural offices to the community without getting permission of the owners of the offices, only 100 names of them are allowed to be known although a petition was formed in order to request help from the Chamber. The names of the architectural design offices were detected by checking the registration list of architectural offices of Ankara. Systematic random sampling method (Bal, 2001) was used in order to select the names of 100 architectural offices among 430. Although all the selected offices were phoned in order to be informed about the survey, only 35 of them were got in touch. Finally, in order to form the sample group of the case study, 100 questionnaires were distributed to the architects working in the 35 participant offices. However, a total number of 86 questionnaires were returned back.

Significant importance was given that questionnaires were responded by the architects having both working and designing experiences. New graduated architects were avoided to respond the questionnaires. Besides, attention was paid not to distribute questionnaires more than three architects working in the same architectural design office.

3.3.2 Procedure

Firstly, a pilot study was performed for the architects, who were determined with the help of snowball sampling method (Bal, 2001). Acquaintance architects working in the offices participated in the pilot study. By means of this study, the appropriateness and the level of being comprehensible of the questions were tested and the reactions of respondents towards questions were observed. Then, after re-designing the questionnaire as an outcome of the pilot study, final survey in the form of questionnaires was carried out. Three stages were defined to constitute the research process and the questions are organized accordingly. The first stage was related to architects' education, working experience in architectural office, and designing experience on seismic zones. Second stage of the questionnaires included questions on the importance of roles and responsibilities of the architects, attitudes of the architects towards seismic design, and their familiarity of architecture-based seismic design issues. The final stage was related to sufficiency of the 1998 Turkish Earthquake Code, necessity of mutual coordination with structural engineer, and the ways for integration of seismic design into architectural design problem (See Appendix B1 and B2 for the questionnaire forms both in English and Turkish versions).

3.4 Results

The data was analysed with statistical software namely 'Statistical Package for the Social Science' (SPSS) Version 13.0. By means of the statistical analyses, frequency distributions, crosstabulations, chi-square tests were used to test the hypotheses (See Appendix A, Table A.1 for the variable list and see Appendix C for the results). The results of the chi-square analyses were evaluated according to the 95 % confidence interval ($\alpha = 0.05$).

In the first part, the questionnaires contain the data referring to the education and experience conditions. Graduation school, existence of post graduation, experience in designing building on seismic zones, and experience in working in an architectural office are the factors that were taken into consideration in testing all the hypothesis **(Table 3.1)**.

Table 3.1: Education and experience characteristics of the respondents

GRADUATION SCHOOL		
	Frequency	Valid Percent
metu	48	57,1
other	36	42,9
EXISTENCE OF POST GRADUATION		
	Frequency	Valid Percent
yes	46	54,8
no	38	45,2
DESIGNING EXPERIENCE ON SEISMIC ZONES		
	Frequency	Valid Percent
yes	52	60,5
no	34	39,5
WORKING EXPERIENCE IN ARCHITECTURAL OFFICE		
Years of Experience	Frequency	Valid Percent
1-5	24	31,2
6-10	16	20,8
11-15	12	15,6
16-20	3	3,9
21-25	12	15,6
26-30	2	2,6
31+	8	10,4

The main hypothesis is about the awareness. It was hypothesized that "architects, who are aware of the importance of the architectural design and its related issues on seismic performance of the building, are conscious about their roles and responsibilities in earthquake resistant building design". 31.8 % of architects stated that architects have much roles and responsibilities in seismic design, where % 42.4 of them stated that they do too much (question 7) (See Appendix C, Table C.1). Moreover, 28 and 24 architects declared that architectural design decisions have much and too much (respectively) effects on seismic performance of the buildings (question 6) (See Appendix C, Table C.2). According to the analyses of frequency distributions, most of the respondents are aware of the importance of the architectural design on seismic performance of buildings and their roles and responsibilities in seismic design **(Figure 3.1)**.

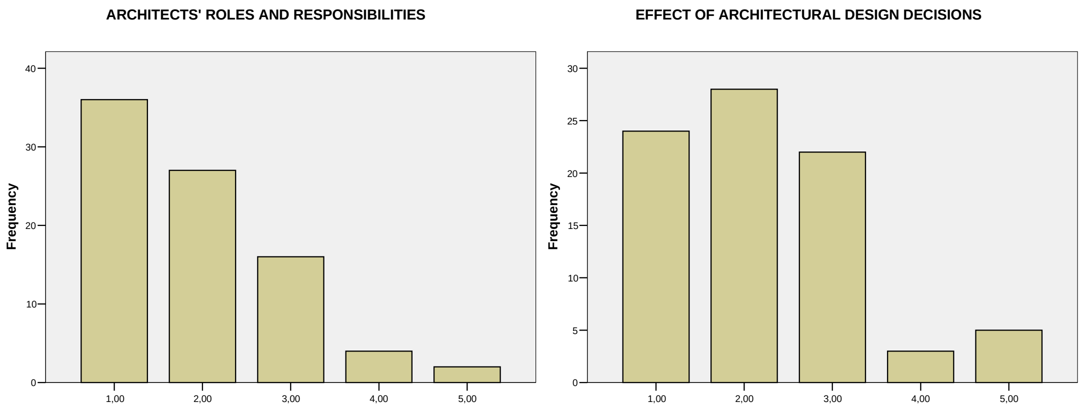

Figure 3.1: Bar charts of roles and responsibilities of architects in seismic design and effect of architectural design decisions on seismic performance
(1: too much, 2: much, 3: average, 4: less, 5: too less)

In relation with this issue, 45.9 % of the respondents strongly agree and 45.9 % of them just agree that seismic design initiates with the architectural design (question 10) (See Appendix C, Table C.3). The frequency distribution also indicates the architects' awareness about the importance of architectural design on seismic performance of buildings.

When the awareness was analysed along with the consideration of architecture-based seismic design issues as design criteria (question 5), it was observed that there is a statistically significant relationship between these two (See Appendix C, Table C.4, x^2=21,326, *df*=6, *p*=0, 002). The significant relationship displays that architects, who consider architecture-based seismic design issues as design criteria with the more ordinary ones, tend to be more aware about the importance of the architectural design and their roles and responsibilities in seismic design.

The architecture-based seismic design issues were asked in order to evaluate the awareness of the architects about them (question 17) (See Appendix C, Table C.5). According to the results:

- 38.4 % of the architects found 'building's form and geometry' important, where 46.5 % of the architects found the issue very important (totally 84.9 %),
- 14 % of the architects found 'building's structural system and its configuration' important, where 83.7 % of the architects found the issue very important (totally 97.7 %),
- 25 % of the architects found 'detailing of the non-structural architectural components' important, where 25 % of the architects found the issue very important (totally 50 %),

The frequency analyses reveal that the respondents are aware of the issues. According to the sample group, much more consideration should be paid to building's structural system and its configuration than building's form and geometry and the least consideration to the detailing of the non-structural architectural components in terms of seismic performance of buildings.

The hypothesis 1 was also analysed along experience and education characteristics of the respondents. Although 52 architects (majority of them) reported that they are experienced in designing buildings on seismic zones (question 3) **(Table 3.1)**, it is interesting that no statistically significant relationship was found between designing experience on seismic zones and the awareness of roles and responsibilities in seismic design, as expected. In the same way, no statistically significant relationship was observed between working experience in architectural offices (question 4) and the awareness of roles and responsibilities in seismic design. However, the experienced architects are expected to become more aware about their roles and responsibilities. On the other hand, when chi-square tests were conducted to find out dependency of the education characteristics (graduation school and existence of post graduation) with the awareness, no statistically significant relationships were found.

The hypothesis 2 is that “architects consider earthquake resistant building design as the province of the engineering profession, which is regarded as the responsibility of structural engineers”. According to results, 21.7 % of the respondents strongly agree and 31.3 % of them just agree that earthquake is an engineering subject (totally 53 %), which is rather related to engineers’ expertise (question 11) (See Appendix C, Table C.6). Moreover, it was observed that 79.8 % of the architects (36.9 %-strongly agree and 42.9 %-agree) in the sample group find structural engineers’ roles and responsibilities much more than architects’ in seismic design (question 12) (See Appendix C, Table C.7). The analyses of frequency distributions explore that majority of the respondents consider ‘earthquake’ as an engineering expertise related to the structural engineers **(Figure 3.2)**.

The result was also checked and confirmed by a control question (question 7) comparing the roles and responsibilities of architects and structural engineers. 96.4 % of the architects stated that structural engineers have much and too much roles and responsibilities (See Appendix C, Table C.8), where 74.1 % of them stated that architects have much and too much roles and responsibilities (See Appendix C, Table C.1). Hence, priority of the roles and responsibilities seems to belong structural engineers as expected.

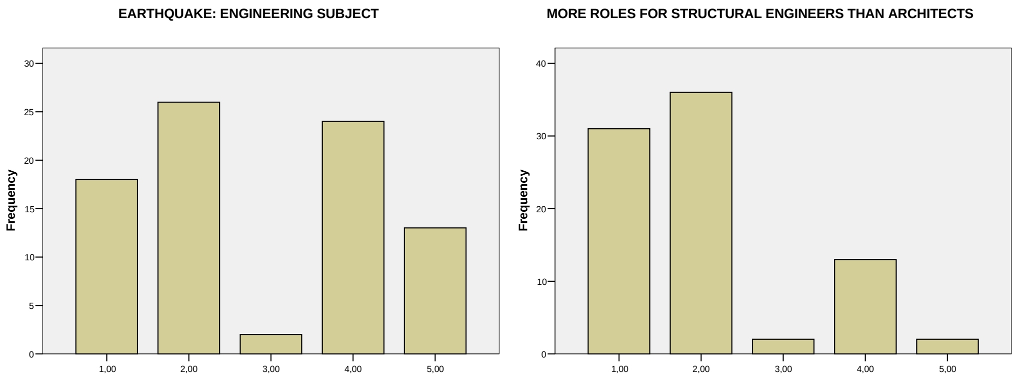

Figure 3.2: Bar charts of earthquake as an engineering subject and comparison of roles of the architects and structural engineers in seismic design
(1-strongly agree, 2-agree, 3-undecided/no idea, 4-disagree, 5-strongly disagree)

In order to search the reasons of regarding 'earthquake' as the province of engineering profession, the study was explored in terms of structural engineers' ability in seismic design. The number of architects in the sample group, who agree that structural engineers are able to transform every building into earthquake resistant ones with the static calculations and alternative solutions no matter how they are designed by architects, are almost equivalent to the ones who disagree (question 13) (See Appendix C, Table C.9). Regarding to this issue, it was observed that 33 respondents tend to leave the process of transforming a building into earthquake resistant one to the structural engineers as an afterthought (question 22) (See Appendix C, Table C.10). The analyses of frequency distributions indicate that the architects, considering 'earthquake' as an engineering subject, generally demand structural engineers to perform seismic performance of buildings as an afterthought. Chi-square tests were established in order to support the relationships. Analyses revealed that statistically significant relationships between the ability of structural engineers and consideration of 'earthquake' as an engineering subject (See Appendix C, Table C.11, x^2=19,995, *df*= 4, *p*=0,001) and seismic design as an afterthought and consideration of 'earthquake' as an engineering subject were present (See Appendix C, Table C.12, x^2=15,528, *df*=4, *p*=0,004). In conclusion, architects in the sample group, who consider 'earthquake' as an engineering subject, tend to leave the process of transforming a building into an earthquake resistant one to the ability of structural engineers.

Consideration of earthquake as an engineering subject (question 11) was also analysed along with education and experience characteristics of the respondents. It is interesting that a statistically significant relationship was observed between the consideration of earthquake as engineering subject and the existence of post graduation (question 2) (See Appendix C, Table C.13, x^2=11,335, *df*=4, *p*=0,023). According to the analysis of crosstabulation (See Appendix C, Table C.13), 27 architects with post graduation did not consider 'earthquake' as an engineering subject, where only 10 architects without post graduation did not. On the other hand, no statistically significant relationships were found among the graduation school, designing/working experience, and consideration of earthquake as an engineering subject.

The hypothesis 3 is about consideration of 'earthquake' as a design criterion. The relevant hypothesis is that "architects do not give adequate consideration to 'earthquake' as a design criterion when it is compared with the more ordinary ones". When the design criteria, such as customer demands, function, aesthetics, environmental factors, standards and regulations, and earthquake (question 5), are taken into consideration, earthquake ranked fourth among them although 85.7 % respondents give much and too much importance to it (1.aesthetics-97.6 %, 2.function-96.4 %, 3.environmental factors-91.8 %, 4.earthquake-85.7 %, 5.standards and regulations-77.6 %, 6.customer demand-70.2 %) (See Appendix C, Table C.14). In relation with this issue, 60.7 % of the architects in the sample group strongly agree and 36.9 % of them agree that 'earthquake' must be considered as a design criterion for architects when they are designing on seismic zones (question 14) (See Appendix C, Table C.15) **(Figure 3.3)**. According to the results, the hypothesis 3 seems to be rejected. Contrary to the null hypothesis 3 (Ho_3) and according to the designed alternative hypothesis 3 ($H1_3$), nearly all of the architects considered 'earthquake' as a design criterion with the other more ordinary ones.

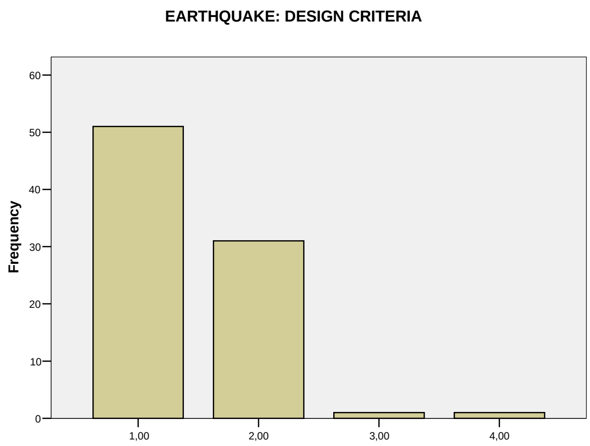

Figure 3.3: Bar chart of consideration of 'earthquake' as a design criterion
(1-strongly agree, 2-agree, 3-undecided/no idea, 4-disagree, 5-strongly disagree)

Although majority of the respondents consider 'earthquake' as a design criterion, some of them found 'earthquake' as an obstacle for architectural creativity. 24 architects feel that architecture-based seismic design issues limit their architectural creativity and artistic freedom while designing, whereas totally 52 respondents, specifically 35 and 17 of them, disagree and strongly disagree (respectively) the situation (question 15) (See Appendix C, Table C.16).

Taking earthquake as a design criterion was analysed in consideration to awareness of the architectural design faults in past earthquakes. Although 63 architects are aware that architectural design faults were the participants of the loss of lives and properties due to damages and collapses of buildings in the past destructive earthquakes (question 8) (See Appendix C, Table C.17), the existence levels of architectural design faults were found at average (between much and less) according to the respondents (question 9) (See Appendix C, Table C.18). This result was supported by the control question (question 16). According to the control question, 13 architects strongly disagree and 40 of them disagree the situation that most of the building damage due to earthquakes were resulted from the architectural design faults, which were formed during design process (See Appendix C, Table C.19).

When consideration of ‘earthquake’ as a design criterion (question 14) was analysed along awareness of architectural design faults in past earthquakes (question 8), a statistically significant relationship was found (See Appendix C, Table C.20, x^2=6,051, *df*=2, *p*=0,049). It is concluded that architects, who are aware of architectural design faults being the participant of damages and collapses of buildings, are more likely to take ‘earthquake’ into consideration as a design criterion.

The hypothesis 3 was also analysed along with education and experience characteristics of the respondents. However, no significant relationships were found among them. In other words, consideration of ‘earthquake’ as a design criterion is not dependent on the graduation school, existence of post graduation, designing experience on seismic zones, and working experiences in architectural offices.

The hypothesis 4 is related to the 1998 Turkish Earthquake Code. It was hypothesized that “1998 Turkish Earthquake Code is not serviceable for the use of architects, therefore some guidance such as regulations for architects needs to be provided”. 72.9 % of the respondents have never examined the irregularities part of 1998 Turkish Earthquake Code, which is more related to architects (question 18) (See Appendix C, Table C.21). Among the architects who have examined it, 42,1 % of them have found it difficult to understand (question 19) (See Appendix C, Table C.22), 38.9 % of them have found it unserviceable (See Appendix C, Table C.23), and 52.4 % of them have found it insufficient (See Appendix C, Table C.24). These analyses of frequencies of the respondents indicate that architects generally are not satisfied from the 1998 Turkish Earthquake Code from architectural viewpoint.

As architects in the sample group agree that 1998 Turkish Earthquake Code is not serviceable for them, they were asked whether guidance is to be provided or not (question 20). 80 % of them stated that it is needed especially in order to integrate architecture-based issues in seismic design into the architectural design process **(Table 3.2)**. This was supported by the statistically significant relationship between serviceability of 1998 Turkish Earthquake Code for architects (question 19) and need for earthquake guidance for architects (question 20) (See Appendix C, Table C.25, x^2=7,367, *df*=2, *p*=0,025). According to the result, only a few architects, who find the code serviceable, do not need guidance.

Table 3.2: Need for guidance for architects (1-yes, 2-no)

NEED FOR GUIDANCE

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1,00	68	79,1	80,0	80,0
	2,00	17	19,8	20,0	100,0
	Total	85	98,8	100,0	
Missing	System	1	1,2		
Total		86	100,0		

When general knowledge of 1998 Turkish Earthquake Code and need for guidance were analysed along with experience conditions of the respondents, statistically significant relationships among them were found. Architects, who are experienced both in designing buildings on seismic zones (See Appendix C, Table C.26, x^2=6,716, *df*=1, *p*=0,01) and in working in architectural offices (See Appendix C, Table C.27, x^2=22,612, *df*=6, *p*=0,001), are more informed about the code when compared with the less experienced ones. Moreover, architects who are experienced both in designing buildings on seismic zones (See Appendix C, Table C.28, x^2=4,424, *df*=1, *p*=0,035) and in working in architectural offices (See Appendix C, Table C.29, x^2=25,449, *df*=6, *p*=0,000), tend to demand guidance, which is to be used during architectural design phase, when compared with the less experienced architects. On the other hand, no relationships were found, when general knowledge of 1998 Turkish Earthquake Code and need for guidance were analysed along the respondents' graduation school and existence of post graduation conditions.

The hypothesis 5, the last hypothesis, is about mutual coordination with structural engineers and it was hypothesized that "there exists a lack of communication between the architect and structural engineer during the architectural design phase, as architects consider seismic design is performed by structural engineer's contributions as an afterthought". 92.8 % of the respondents stated that they have mutual coordination with structural engineer during architectural design process including seismic design issues (question 21) (See Appendix C, Table C.30). In relation with this issue, 94.2 % of the architects in the sample group consider the negotiation, during architectural design process, important in terms of seismic performance of the buildings (question 24) (See Appendix C, Table C.31). As a result, the first part of the hypothesis 5 (Ho_5) seems to be rejected. According to the first part of the designed alternative hypothesis 5 ($H1_5$), communication between the architect and the structural engineer during the architectural design phase exists.

On the other hand, respondents, who are more likely to have mutual coordination with the structural engineers during architectural design phase, are more aware of their roles and responsibilities. According to the analysis of crosstabulation, total number of 60 architects (specifically 35-too much and 25-much) having mutual coordination about the seismic design issues, consider that architects have too much and much roles and responsibilities in seismic design (See Appendix C, Table C.32). It was supported by a statistically significant relationship between these two (See Appendix C, Table C.32, x^2=10,232, *df*=3, *p*=0, 017).

The second part of the hypothesis 5 was tested in order to find out whether seismic design is thought to be an afterthought or not. Although the percentage of the architects, who leave the process of transforming a building into earthquake resistant one to the structural engineers, was not as high as the opposed portion, it was significant: 41.3 % (question 22) (See Appendix C, Table C.33). It was supported by the results of the control question (question 13). According to the control question, the number of architects relying on structural engineers' ability was almost equivalent to the opposed ones (See Appendix C, Table C.9).

In terms of the relationship of the two parts of the hypothesis, a significant number of architects (31 out of 74) considered seismic design as the structural engineers' contribution, although they generally have mutual coordination with structural engineers **(Table 3.3)**. However, according to the chi-square analysis, no significant relationship was found between the parts of the hypothesis 5. In other words, finding 'earthquake' as an afterthought is independent from the existence of communication between the architect and structural engineer during the architectural design phase.

Table 3.3: Relationship for the mutual coordination with structural engineer (question 21) and consideration of seismic design as an afterthought (question 22) (1-yes, 2-no)

MUTUAL COORDINATION * STRUCTURAL ENGINEERS' SUPPLEMENT Crosstabulation

Count

		STRUCTURAL ENGINEERS' SUPPLEMENT		
		1,00	2,00	Total
COORDINATION	1,00	31	43	74
	2,00	2	3	5
Total		33	46	79

A chi-square test was conducted to find out whether the mutual coordination between the architects and structural engineers is affected by disagreement/conflict. 46.3 % of the architects have experienced disagreement/conflict with structural engineers about the seismic issues during mutual coordination (question 23) (See Appendix C, Table C.34). However, no statistically significant relationship was found between them.

Finally, hypothesis 5 was also analysed along with education and experience characteristics of the respondents. However, no significant relationships were found among them. Mutual coordination is not dependent on the graduation school, existence of post graduation, designing experience on seismic zones and working experiences in architectural offices.

3.5 Discussion

First issue that the case study focused on is to explore how architects experience and perceive seismic design: roles, responsibilities, awareness, and knowledge of architecture-based seismic design issues. In order to conclude according to the analyses of the data:

1. Most of the respondents are aware of the importance of the architectural design on seismic performance of buildings, the architecture-based seismic design issues (respectively: building’s structural system and its configuration, building’s form and geometry, and detailing of the non-structural architectural components) and accordingly their roles and responsibilities in seismic design (hypothesis 1).

It is obvious that in addition to architects and structural engineers, contractors and controllers have also important roles and responsibilities for seismic safety of buildings. Some respondents added some other professionals and factors related to building construction for sharing the roles and responsibilities of seismic safety. These are geo-technical engineers, project managers, standards and regulations, municipalities and ministries, landowners, schools and universities, users, community, and even workers.

2. Most of the respondents consider ‘earthquake’ as an engineering expertise related to the structural engineers. Priority of the roles and responsibilities seems to belong structural engineers rather than architects (hypothesis 2). Moreover, a significant number of architects, but not the majority, generally demand structural engineers to perform seismic performance of buildings as an afterthought.

3. Earthquake is taken into consideration as a design criterion with the more ordinary ones such as customer demands, function, aesthetics, environmental factors, and standards and regulations, when architects are designing on seismic

zones (hypothesis 3). On the other hand, almost 1/3 of the respondents consider 'earthquake' as an obstacle for architectural creativity.

'Personal design concerns (what the architect wants to design), life security, static security, precautions related to soil conditions, budget, and construct-ability' are the additional design criteria that were mentioned by some of the respondents.

4. Most of the respondents have never examined the 1998 Turkish Earthquake Code. Architects, who have examined it, generally are not satisfied with the code from architectural viewpoint. Most of them demand guidance in order to integrate architecture-based seismic design issues into the architectural design process (hypothesis 4).

5. Most of the respondents are aware of the importance of the negotiation performed during architectural design process in terms of seismic performance of the buildings. Therefore, they have mutual coordination with structural engineers including seismic design issues (hypothesis 5). However, a significant percentage of the architects has experienced disagreement/conflict with structural engineers and generally leaves the process of transforming a building into earthquake resistant one to the structural engineers' ability.

Second issue that the case study focused on is to investigate the possible ways to enhance the incorporation of 'earthquake' as a design parameter with the other and more ordinary ones such as customer demand, environmental factors, and so on. In order to satisfy the condition, three alternatives were offered with the questionnaire (question 25). These are:

- *Guidance for architects should be prepared:* 62.4 % of the architects in the sample group considered this alternative as a way in order to incorporate 'earthquake' as a design parameter (See Appendix C, Table C.35).
- *Architecture-based issues in seismic design should be taught in details during architectural education:* 81.2 % of the respondents signed this alternative as

a way in order to incorporate ‘earthquake’ as a design parameter (See Appendix C, Table C.36).

- *The amount of mutual coordination with the structural engineers should be frequent:* 64.7 % of the architects chose this alternative as a way in order to incorporate ‘earthquake’ as a design parameter (See Appendix C, Table C.37).

Some of respondents stated additional ways to enhance the incorporation of ‘earthquake’ as a design parameter. These are: encouragement and introduction of the earthquake resistant building systems, productions, and materials; investigation of technological advances; proper detailing throughout the construction; giving importance to the use of steel instead of reinforced concrete; examination of damaged buildings due to earthquakes; giving consideration to the site summer work in architectural education, besides doing summer work that comprises all the seismic zones from 1st degree to 4th one; exploration of international architectural design competitions comprising earthquake consciousness; and organization of seminars and presentations related to the architectural design solutions and advances in seismic design.

According to the comments, which were added by some of the respondents, there exist factors that affect the earthquake resistance of buildings in negative manners apart from the architectural concerns. Although a building is designed with the consideration of earthquake from the first sketches of the design process, it may turn to be unresistant one due to incorrect and deficient material choice and usage, improper production of construction, lack of control during construction phase and improper usage of buildings (operations that change the static characteristics of the building such as demolishing or constructing partition walls).

As earthquake is the reality of the geographic structure of Turkey, Turkish people must learn how to deal with it. It is necessary to make not only architects but also everyone on the country have the consciousness of being aware that Turkish people have been living on a country being prone to earthquakes and they have been living with earthquake risk for many years. In this respect, education is one of the most important concerns in order to form consciousness and awareness.

From the architects' viewpoint, although Turkey is a country, which is likely to subject severe earthquakes, there exist no departmental and 'must' course related to seismic design in the departments of architecture, for instance in the Department of Architecture at Middle East Technical University. However, students of architecture, as being the future designers of the buildings, are to be informed about the architecture-based seismic design issues. On the contrary, well-known earthquake experts give lectures to the students of architecture at Berkeley University, as earthquake risk is also present for California. Therefore, it is a critical and a vital concern that architects should have the basic knowledge or general idea about earthquake resistant building design issues from architectural viewpoint. Designing earthquake resistant buildings should be the main aim of the operation of architectural design process. This is why; value of life safety must exist over all the other concerns.

One of the respondents of the case study states that:

No matter how the architecture of a structure is, it is possible to transform it into an earthquake resistant one. The important concern is the technology, which is used and reached.

This is partially true. Any architectural project may be turned into an earthquake resistant one with the help of sophisticated earthquake analyses and computerised computations. However, this case is directly related to budget. Due to economical impossibilities, it is rather difficult, even impossible, to reach and to use seismic technology for every single building and structure on the country, as 95 % of geographical land of Turkey is situated on the 1st and 2nd earthquake prone zones, which is likely to subject severe earthquakes.

Besides, everyone tries to employ in construction work and this work is performed by the ones, who are unrelated to the profession of construction. It is not logical to expect non-professional contractors to make use of technology; even they mostly do not build according to an architectural project, instead of this, they generally imitate the architectural design of neighbouring buildings (even the configuration of structural system) with a 'mass-production' mentality. Therefore, budget is also an important consideration for them. In conclusion, the important concern is level of awareness and consciousness of architects. Architects should begin to design by taking earthquake into consideration.

CHAPTER 4

ARCHITECTURE-BASED ISSUES IN SEISMIC DESIGN

The architectural design decisions that influence the seismic performance of the buildings can be classified into three groups:

- Building configuration issues (as a whole),
- Structural system configuration issues (in plan and in vertical),
- Non-structural architectural components' configuration issues (with their architectural detailing).

Although the classification is changeable, it is serviceable in order to understand their influences on seismic performance and the interactions among groups.

Dowrick (1987) states that the configuration of the construction is the geometrical arrangement of all of the elements: architecture, structure, equipment, and contents. Consideration of configuration must include concerns both for the form of the building as a whole and the form of the structural and non-structural system of the building. They are all determined by the architects during the architectural design process.

4.1 Building Configuration Issues

According to Arnold (1989), there exist three major determinants of building configuration. These are:

- building function and planning,
- urban design and planning requirements,
- need for a distinctive or attractive image.

The final configuration is the balance of these varying requirements within an architectural concept and a budget.

Arnold (1989) points out that “for a given ground motion, the major determinant of the total inertial force in the building is the building mass” (p.144). The form and the size of the building with the choice of materials establish the mass. As configuration mostly determines how seismic forces are distributed throughout the building, it is an important consideration from seismic point of view. It also influences the relative magnitude of seismic forces. A variety of configuration can be designed for any architectural program, each of which affects the distribution of seismic forces differently. For a better seismic performance, ‘regular’ configuration, which means the optimum or ideal configuration in dealing with lateral forces (such as earthquake forces), should be designed. ‘Regular’ configuration should be present both in plan and in vertical. However, sometimes functional requirements and architectural creativity dictate less ideal seismic configurations. Actually, the variety prevents the built environment to become a boring place (Arnold, 1989).

On the other hand, the term ‘regularity’ does not mean symmetric and repetitive solutions, which are limited by a strict set of principles. It is rather searching for solutions appropriate for seismic behaviour of buildings that are in harmony with technological innovations (Mezzi, Parducci and Verducci, 2004).

4.1.1 Form / Geometry

According to Mezzi, Parducci and Verducci (2004), the shape has been recognized as a fundamental parameter in controlling buildings’ response to earthquake forces. As Ambrose and Vergun (1985) state, “the form of a building has great deal to do with the determination of the effects of seismic activity on the building” (p.48). For a good seismic performance, regular configuration is obtained by simplicity and symmetry of the building form.

Simplicity

Earthquakes repeatedly demonstrate that the simplest structures have the greatest chance to survive after severe earthquakes. According to Dowrick (1987), there are three main reasons for this:

- The ability to understand the overall behaviour of a simple structure is greater than it is for a complex one. Therefore, unpredictable stress concentration that may cause local collapses and modifications of the dynamic behaviour are avoided (Mezzi, Parducci and Verducci, 2004).
- The ability to understand simple structural details is considerably greater than it is for complicated ones.
- Simple structures are likely to be more buildable than complex ones.

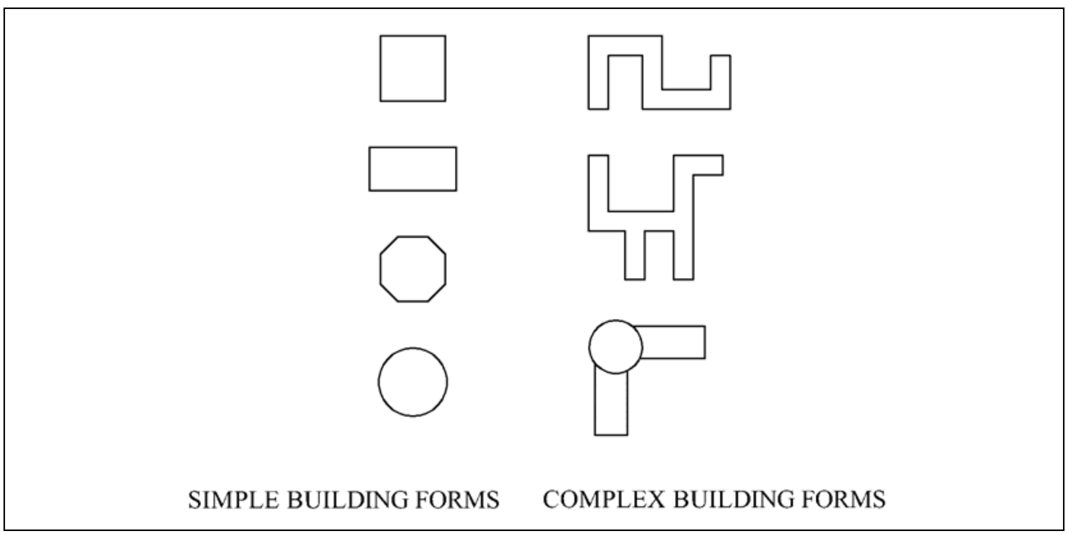

Figure 4.1: Simple and complex building forms

The most appropriate form of a building is a square or a circle from seismic point of view. A regular building form, which is simple and symmetric, proves the same rigidity in all directions. Accordingly, seismic forces acting to the buildings do not vary. In this respect, circle is the most ideal building form. However, generally it is not appropriate for analyses, construction, and functional requirements. A rectangular form approaching to a square, which is not so long in plan, is also an appropriate building form in terms of simplicity and symmetry **(Figure 4.1)** (Bayülke, 2001).

The shape of the building can become a negative factor as an irregularity in itself. This is mainly because of its effect on the structural system. Irregularities in the structural system are determinant in reducing the seismic performance of buildings. When a complex form is to be designed, the structural cost must be acknowledged. Moreover, appropriate three-dimensional earthquake analyses should be done in the design process (Ambrose and Vergun, 1985; Dowrick, 1987; Mezzi, Parducci and Verducci, 2004).

Symmetry

As Arnold (1989) states, "the term symmetry denotes a geometrical property of building plan configuration" (p.150). It is desirable to have symmetry both in the form of the building as a whole (architectural symmetry) in three directions **(Figure 4.2)** and in the disposition of the structural elements of the lateral resistive system (structural symmetry). Otherwise, torsional effects are produced leading to destruction of building.

The critical concern is the coincidence of the center of building mass (generally considered as the geometrical center of the building) with the center of rigidity (considered as the center of vertical elements of the structural system) **(Section 4.2.1.2).** When a building is not architecturally symmetrical, the structural system must be adjusted so that the center of rigidity becomes close to the center of the mass (Ambrose and Vergun, 1985).

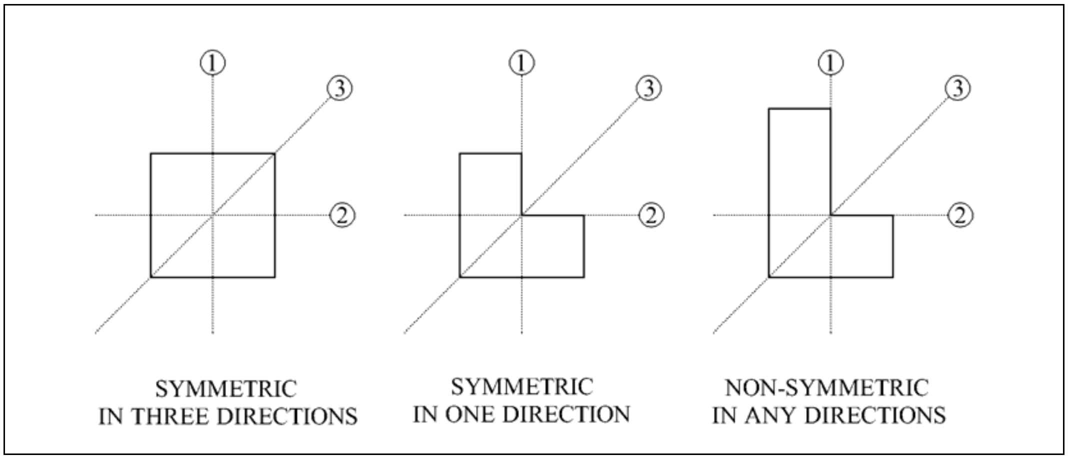

Figure 4.2: Architectural symmetry

A building with re-entrant corners **(Section 4.1.3)** is not necessarily asymmetrical, but it is irregular. Thus, symmetry is not sufficient on its own and it is beneficial only when it is combined with simplicity. When good seismic performance is to be achieved with maximum economy of design and construction, symmetrical and simple forms should be preferred. However, architectural requirements often make the symmetrical design impossible. In these circumstances, it may be necessary to take precautions (Arnold, 1989).

Sometimes, although a building, whose form is a square or a rectangle, is simple and symmetrical in overall plan, torsional forces may be created due to the irregularities inside the building. The irregularities may result from the rigidity differences of diaphragms **(Section 4.2.1.3)**, improper shear wall design or unsymmetrical location of service cores (Bayülke, 2001).

4.1.2 Scale, Size and Proportion

The length, the height, and the proportions of these two have influences on seismic performance of the building.

Length

Limiting the size of a building in plan and making it compact are important considerations for seismic performance of a building. When a plan becomes extremely large, even if it is symmetrical and simple, it may have problems in responding to the ground movements as one unit (Arnold, 1989). Because, a building with elongated plan is likely to have different ground movements applied along its length. Moreover, a building with a long and an extended form in plan experiences greater variation in soil conditions. This variation may be due to differences in geological conditions (Dowrick, 1987).

When a long building is needed for planning reasons, the solutions are:

- to subdivide the building into separate short lengths and compact forms with movement gaps between them (the use of seismic separation joints) **(Figure 4.3)** (Coburn and Spence, 1992),
- to add lateral force resisting elements (shear walls and columns) in order to reduce the span of the diaphragm **(Section 4.2.1.3),** although this may introduce problems in the use of the building (Arnold, 1989),
- to chose the appropriate types of the foundation **(Section 4.2.2.6)** (Dowrick, 1987).

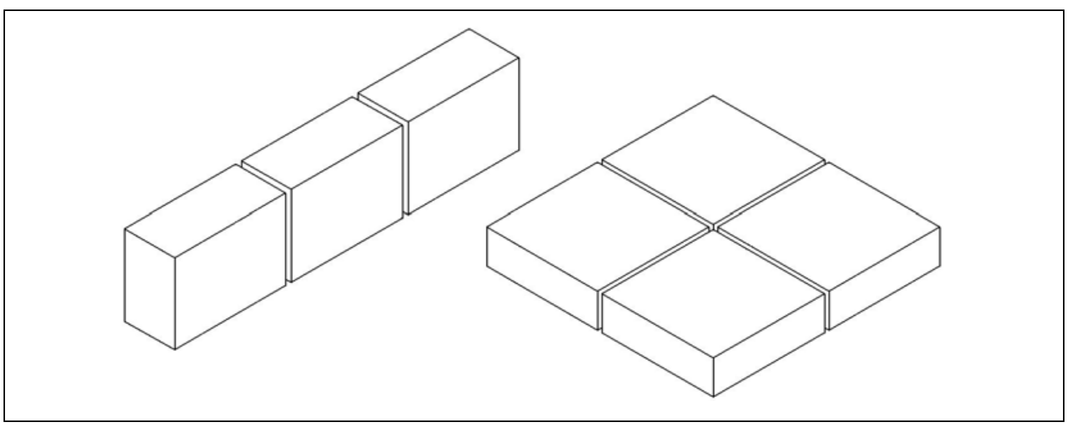

Figure 4.3: Subdivision of the building into compact forms

Height

Although there had been some limitations on building dimensions in earthquake prone zones for the past years, with the introduction of new materials with greater strength, it has been recognized that height is not a negative factor for the seismic response. In fact, a greater height can increase the natural period of the building and shift it in the range where the response is lower (Mezzi, Parducci and Verducci, 2004).

In **Figure 4.4**, three different building profiles illustrate different potential responses to earthquake loads with regard to the natural period of vibration and the lateral deflection. In general, as the rigidity increases, the natural period of vibration of a building becomes shorter (Architectural Institute of Japan, 1970). The short and rigid building tends to absorb larger earthquake loads because of its quick response (short natural period of vibration). On the other hand, the tall, slender, and flexible building responds slowly to earthquake loads having long natural period of vibration. It dissipates the seismic energy in its motion. However, much deflection may create deformation problems (Ambrose and Vergun, 1985).

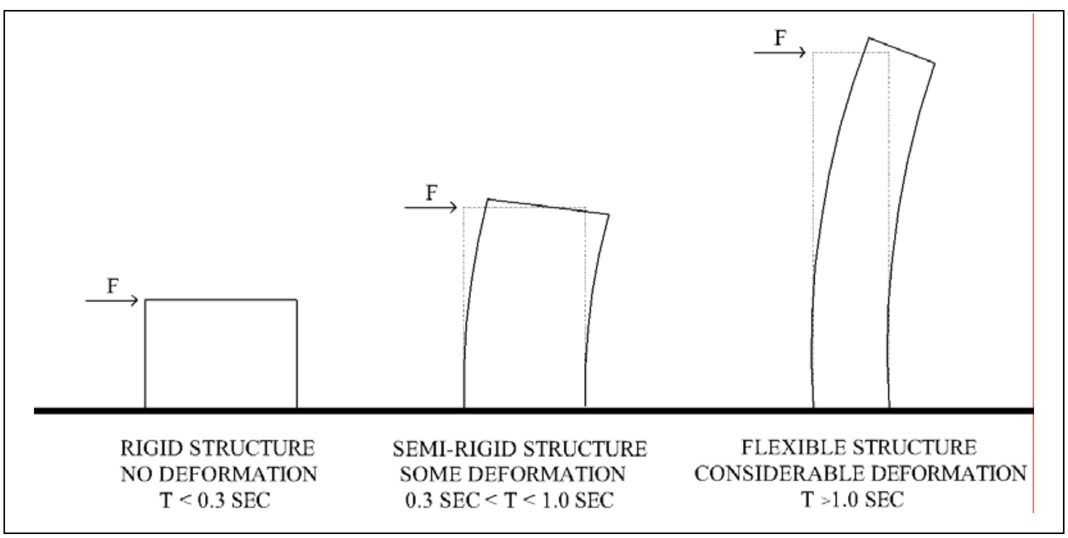

Figure 4.4: Seismic response of buildings with different heights

As urban land becomes more expensive, there is a trend towards designing very tall buildings, which may have a large slenderness (height / depth) ratio. It is not illogical to build tall buildings on earthquake zones. Because tall buildings generally have complete earthquake analyses and construction processes. Moreover, they tend towards symmetry and simplicity. According to Arnold (1989), the seismic problems are most apparent in the medium height buildings, where considerable choice of plan forms and the multi masses of buildings exist. Yakut, Gülkan, Bakır and Yılmaz (2005) state that half of the buildings, which damaged (light, moderate and severe) and collapsed in the August 17, 1999 Kocaeli Earthquake, were five stories in height. The next largest group is for six-storey buildings comprising 32 % of the total. On the other hand, as the height of the building increases, two important seismic problems come to existence. These are resonance and overturning effect.

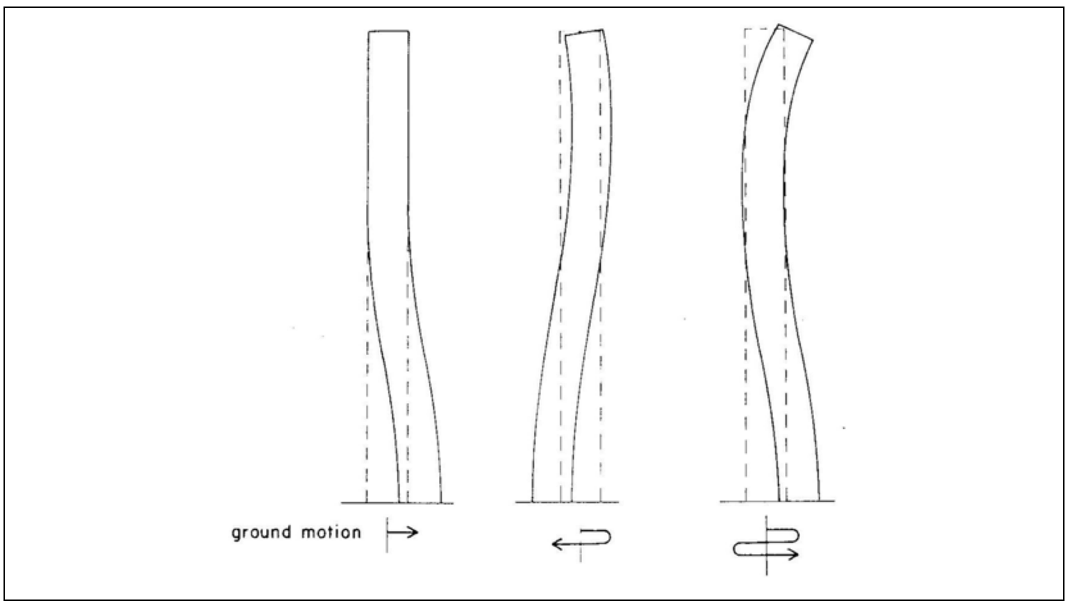

Figure 4.5: Resonance in tall buildings (Ambrose and Vergun, 1985, p.23)

When the natural period of vibration of a building coincides with the natural period of ground, a synchronized resonance between the two occurs **(Figure 4.5)**. If the building exceeds its elastic range by absorbing the earthquake forces, it may come to the fracture point resulting in failure or total collapse. So, the effect of the building period must be considered in relation to the period of ground movements. In the design of tall buildings, the architect must realize the importance of the relationship (Lagorio, 1990).

It is important to compare the natural periods of vibration of building and ground and to prove the tall building not to suffer from resonance. If they are close to each other, precautions should be taken against earthquake loads by adjusting building configuration and structural configuration. Thus, the natural periods of vibration of the building and the ground become differentiated from each other (Zacek, 1999).

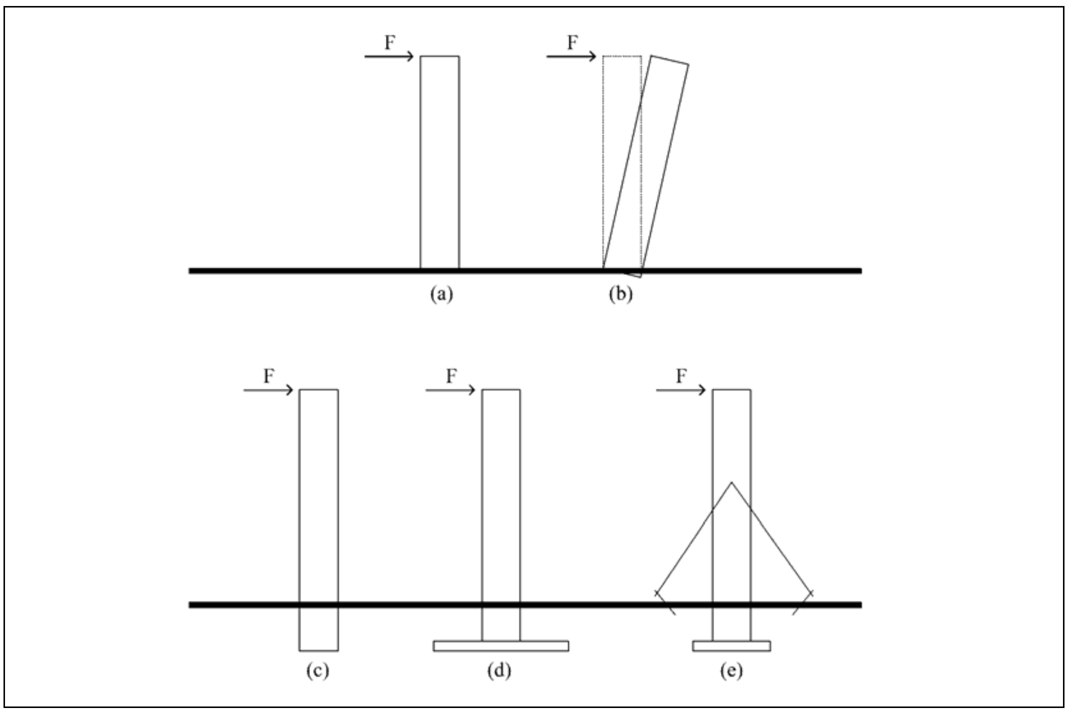

Figure 4.6: Overturning

As the overturning effect is related to the vertical form of the building, tall and slender buildings are highly vulnerable to overturning. Overturning results in the building to tip over with or without its foundation **(Figure 4.6a, Figure 4.6b)**. There exist techniques in order to resist overturning. According to Ambrose and Vergun (1985), these are:

- to modify the existence supports **(Figure 4.6c)**,
- to spread the base in order to increase the moment arm for stabilizing moment **(Figure 4.6d)**,
- to add a separate and an external bracing system **(Figure 4.6e)**.

Proportion

Arnold (1989) states that in seismic design, the proportions of a building may be more important that its absolute size. For tall buildings, the ‘slenderness ratio’ (height / depth) of a building is a more considerable issue than just ‘height’ (Coburn and Spence, 1992). A building with a large slenderness ratio exhibits large lateral displacement under lateral forces. Very slender buildings should be avoided in strong earthquakes zones. Because, the axial-column force due to overturning moment in a slender building tends to become very large. Moreover, their foundation stability may be difficult to achieve because of the forces acting on the foundation (Dowrick, 1987; Wakabayashi, 1986).

Dowrick (1987) states that the slenderness ratio of a building should not exceed about 3 or 4, otherwise it leads to uneconomical structures and requires dynamic analyses for proper seismic response. On the other hand, Zacek (1999) states that it is recommended not to design a building whose ratio of the sides to one another is greater than 3 **(Figure 4.7)**.

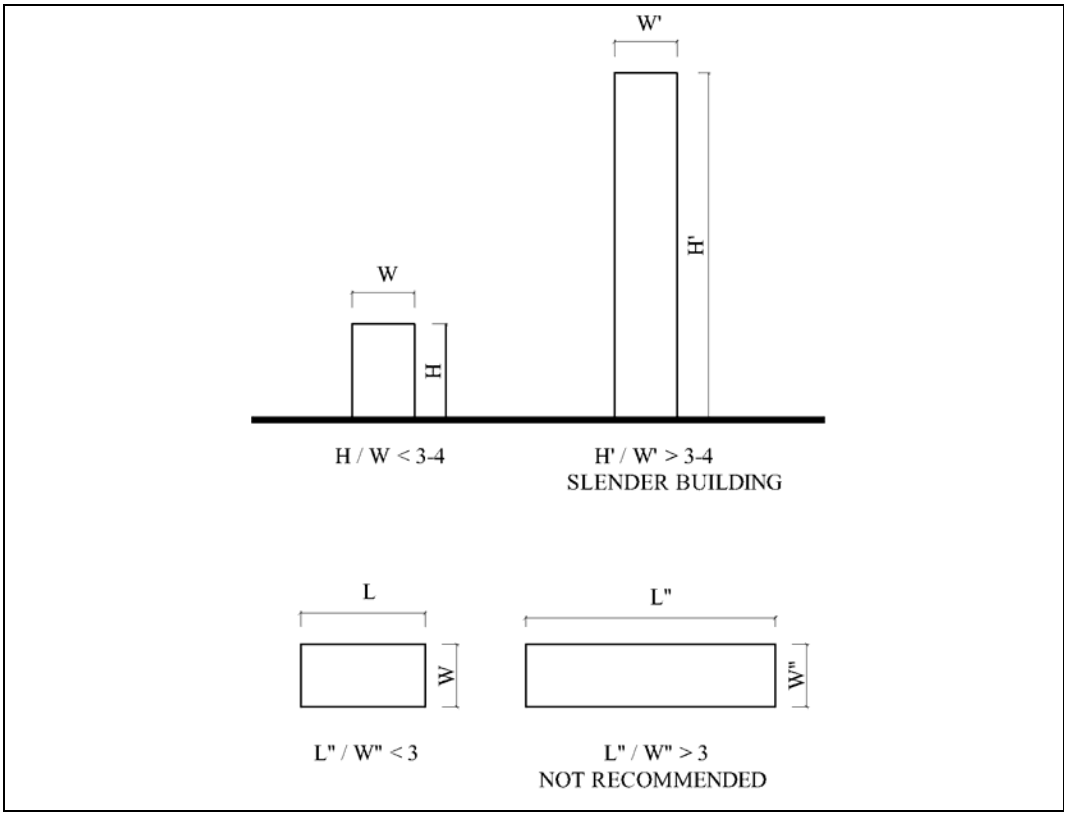

Figure 4.7: Proportions

4.1.3 Building with Re-entrant Corners and Multi-massed Buildings

The shape of H, L, T, U, Y, +, or a combination of these forms are the typical examples of building configuration which have projections or wings in plan constituting re-entrant corners **(Figure 4.8)**. They are commonly designed for high-density housing and hotel projects as they enable large plan areas in compact forms, which have different vistas and lighting opportunities from different angles (Arnold, 1989).

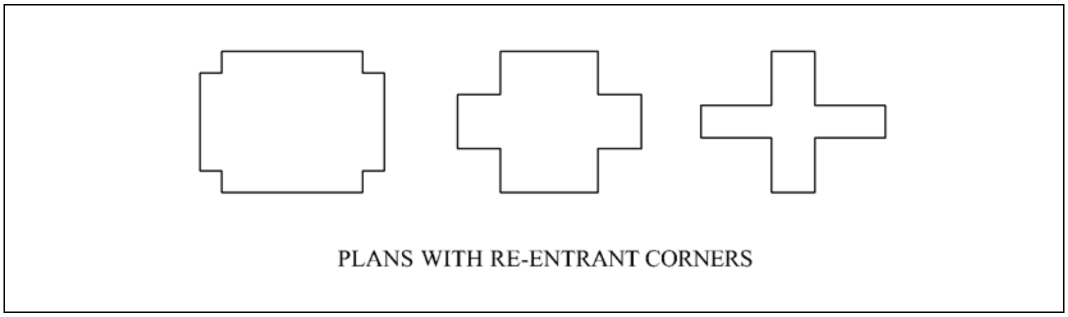

Figure 4.8: Re-entrant corners in plan

The 1998 Turkish Earthquake Code states the ratio of the projections to the entire plan, as they are important in terms of seismic behaviour of the building.

A3 – Projections in Plan:

The cases where projections beyond the re-entrant corners in both of the two principal directions in plan exceed the total plan dimensions of the building in the respective directions by more than 20%.

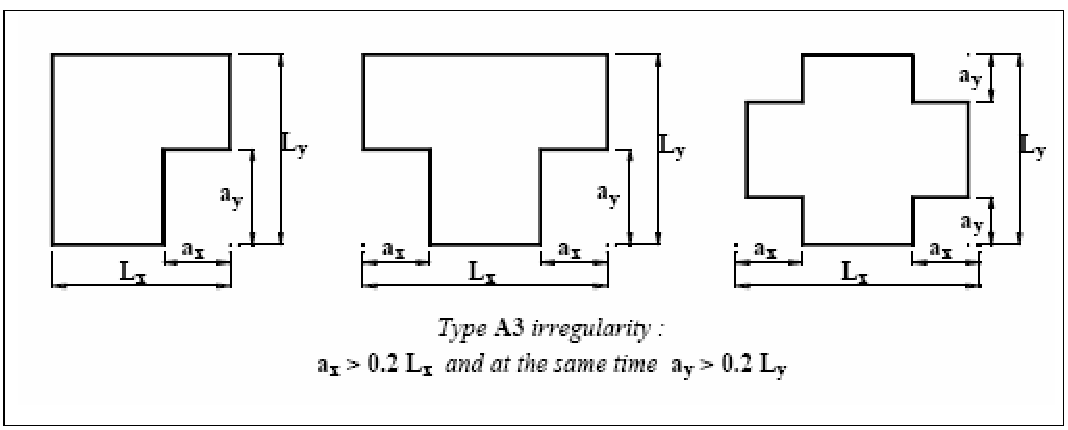

Figure 4.9: Projections in Plan (Turkish Earthquake Code, 1998, p.9)

Wakabayashi (1986) states that the buildings having projections (or wings) have often been severely damaged in earthquakes. There are two related problems created by these forms. The first problem is local stress concentration at the 'notch' of the re-entrant corner where the wings meet. This is due to the variations of rigidity and different movements of the different parts of the building. The second problem is torsion. This is because the center of mass and the center of rigidity in this form cannot geometrically coincide for all possible earthquake directions. The result is rotation, which tends to distort the form and results in torsional forces that are very difficult to analyse and predict (Arnold, 1989).

The seismic performance of an L-shaped building shown in **Figure 4.10** is an example. Each wing of the L-shaped building experiences different deformation depending on the incoming direction of the earthquake forces. Under the influence of the earthquake force, wing 'A', which is parallel to the direction of earthquake force, is stiffer than wing 'B' because of its more rigid axis. On the other hand, wing 'B', which is perpendicular to the direction of earthquake forces, is more flexible than wing 'A' and its seismic performance is weaker in that direction. As a result, undesirable torsional forces are introduced in this type of plan configuration under the influence of earthquake motions, causing rotation of wing 'B' relative to the center of rigidity of the L-shaped building. Unless the two wings are designed with the capacity to resist and dissipate the torsional effects adequately, the building system may severely damage, particularly at the notch (Lagorio, 1990).

However, according to Faella, irregularity of a L-shaped plan becomes only 'apparent' if provisions such as designing rigid diaphragms **(Section 4.2.1.3)** are adopted in order to avoid the dangerous local effects and if the distribution of the lateral force resisting elements fit to the geometry. Consequently, very slight torsional effects come into existence that can be accounted for at design stage (Mezzi, Parducci and Verducci, 2004).

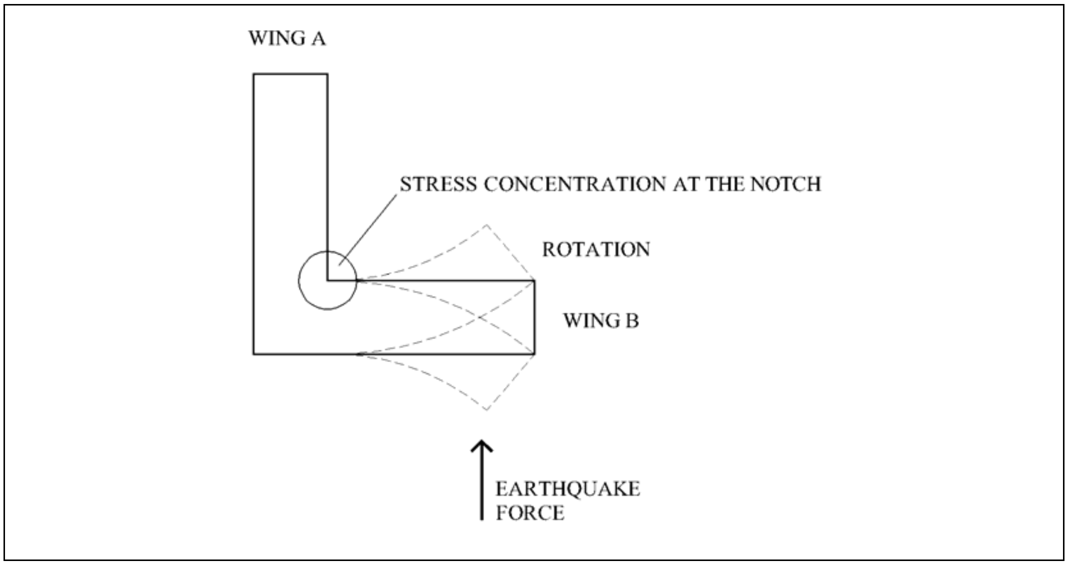

Figure 4.10: L-shaped building behaviour under earthquake force

According to Arnold (1989), the stress concentration at the notch and the torsional effects are interrelated. The magnitude of the forces and the serious of the problem depend on:

- the mass of the building,
- the structural system,
- the length of the wings and their ratios,
- the height of the wing and their slenderness ratios.

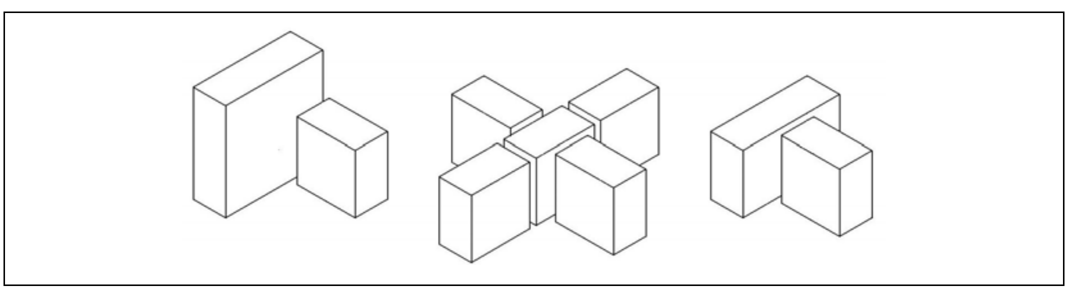

Figure 4.11: Separation of buildings into portions

In general, there exist two alternative solutions in order to overcome the problem. These are:

- to separate the building structurally into simple forms **(Figure 4.11)**,
- to tie the building together strongly at lines of stress concentration and to locate resisting elements to reduce torsion (Arnold, 1989).

In order to permit independent movements of substructures, actual dimension of separation between adjacent structures (with the use of seismic separation joints) must be provided to ensure that no hammering **(Section 4.1.5.1)** occur (Ambrose and Vergun, 1985; Paulay and Priestley, 1992). According to Arnold (1989), as the free ends of the wings tend to distort most under torsion, it is desirable to place structural elements at this locations **(Figure 4.12)**.

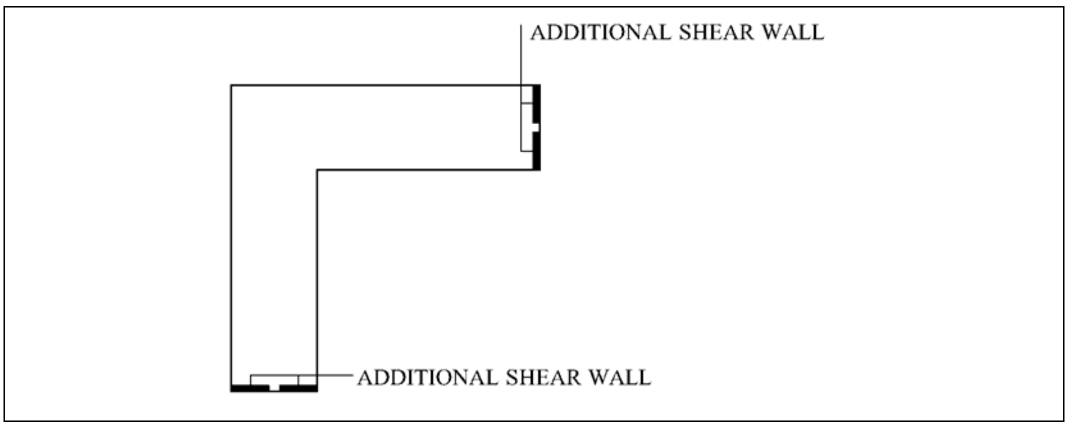

Figure 4.12: Additional shear wall to free end of wings

The use of splayed re-entrant corners rather than right angle ones **(Figure 4.13a)** (Arnold, 1989) or softening the right angle re-entrant corner **(Figure 4.13b)** (Zacek, 1999) lessens the stress concentration at the notch. According to Zacek (1999), another solution to reduce the stress concentration at the notch is to increase the section of the vertical structural element, which is placed at the notch.

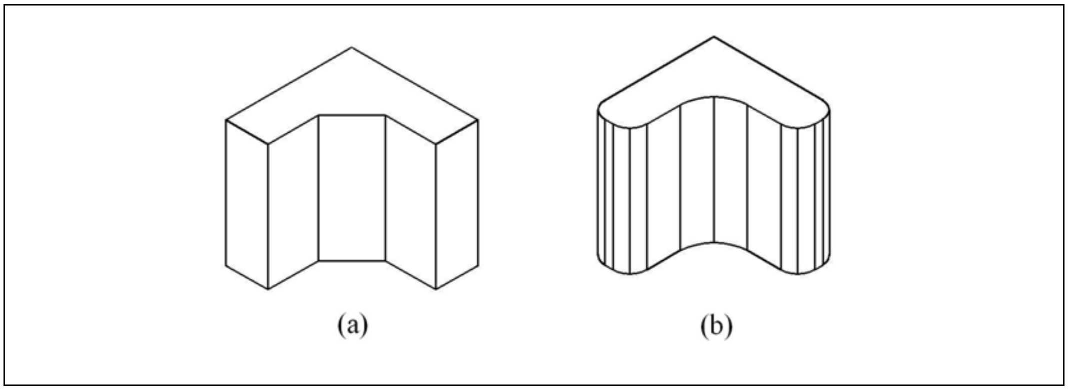

Figure 4.13: Softening the right-angle re-entrant corner

The architectural separation of the masses is sometimes emphasized with a linkage element **(Figure 4.14)**. Sometimes, two buildings are joined with elements such as staircases or transition parts. These elements may damage during earthquakes. In order to avoid the problem, separating the connection part from the main buildings with seismic joints and considering it as a self-standing structure is the most appropriate solution (Zacek, 1999). Besides this, it may be designed strong enough in order to behave as a continuous structure during earthquake movement or it may be separated from one side and attached to the other side in order to behave as a part of the attached side (Ambrose and Vergun, 1985).

Individual joined masses are sometimes so different in size or stiffness. In this case, the smaller part is simply attached to the larger one, treated as attachments without developing their own bracing. It is called tag along structure **(Figure 4.14)**. The tag along technique is often used for elements having lightweight compared with main structures such as staircases, chimneys, entries, connecting corridors, and other elements that are part of a building, but are generally outside the main mass (Ambrose and Vergun, 1985).

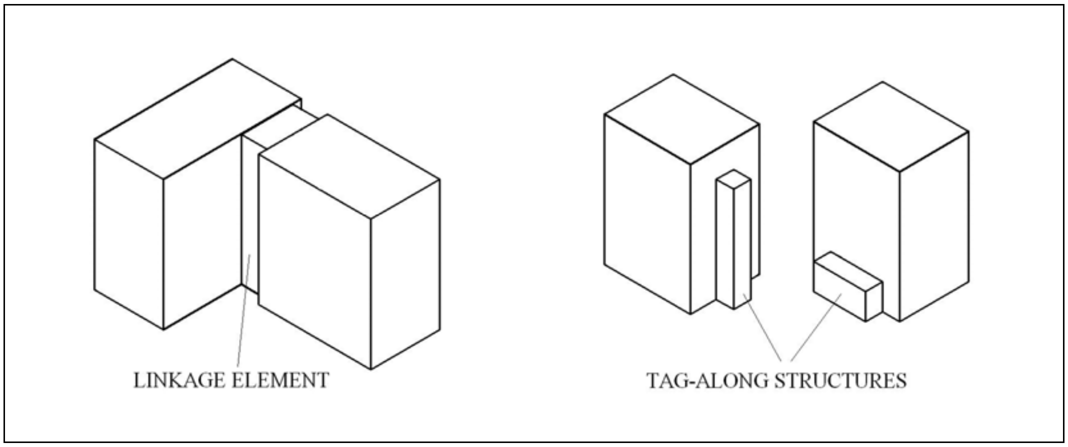

Figure 4.14: Buildings with linkage element and tag-along structures

4.1.4 Buildings with Vertical Setbacks

A setback is an abrupt change of strength and stiffness in elevation, which are likely to invite poor structural responses. A setback may be introduced for several reasons. Arnold (1989) states that the seriousness of the setback effect depends on the relative proportions and absolute size of the separate parts of the building. As the absolute size of setback increases, the amount of the deformation increases.

For example, as the slenderness ratio of a tower increases, the risk of overturning of the tower on to the base portion becomes apparent **(Figure 4.15)**. As the tower and the base do not have the same natural period of vibration, their responses to earthquake forces are different in phase. So, opposite displacements may occur, which result in stress concentrations at and near the level of discontinuity. They are difficult to predict without sophisticated computerized analytical methods. Moreover, even if known, the building could not be adequately detailed at the critical spots (Zacek, 1999). Therefore, according to Zacek (1999), it is desirable that each floor has the same shape in plan.

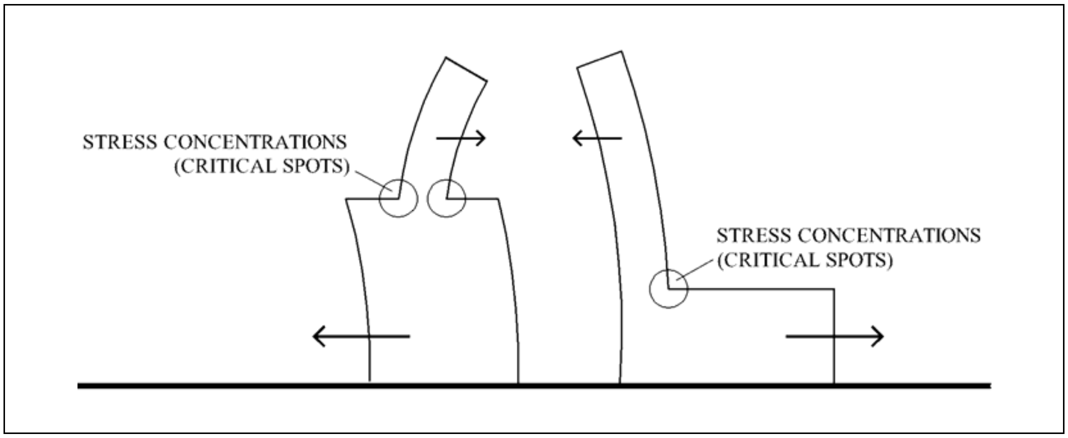

Figure 4.15: Stress concentrations due to setbacks

Arnold (1989) states that solutions for the setback problem are similar to those for the re-entrant corner (its horizontal counterpart in plan). According to Zacek (1999), the solutions for reducing the negative effects of the setbacks are:

- to separate the portions in vertical **(Figure 4.16)** (so that portions of the building (base and the tower) are free to react independently),
- to remove the re-entrant corners by gradually reducing building form,
- to reinforce the re-entrant corners on vertical.

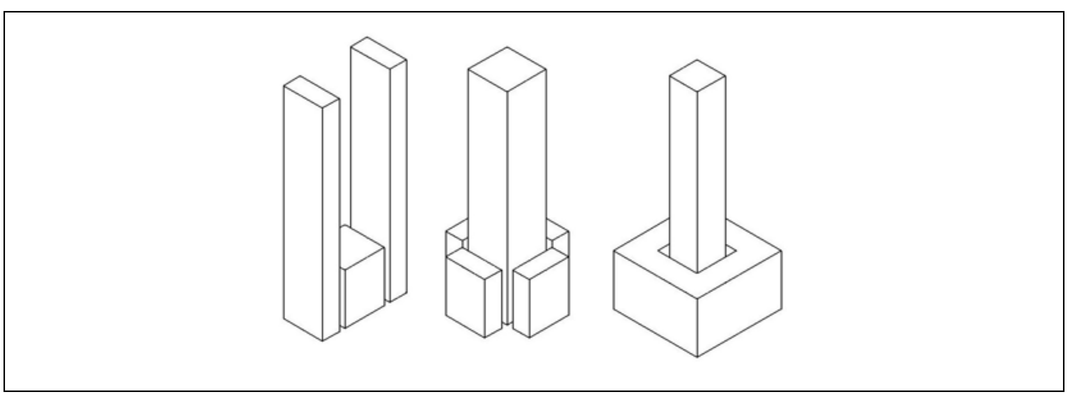

Figure 4.16: Separating the portions of the buildings

A type of setback configuration in which the building grows larger with height, is called inverted setback **(Figure 4.17)**. Although it has powerful design attractiveness, because of the problems of overturning it has appeared less. Arnold (1989) states that the inverted setback configuration of any extreme form and size should be avoided in seismic areas, unless the considerable additional extra structural cost is to be paid for the analyses.

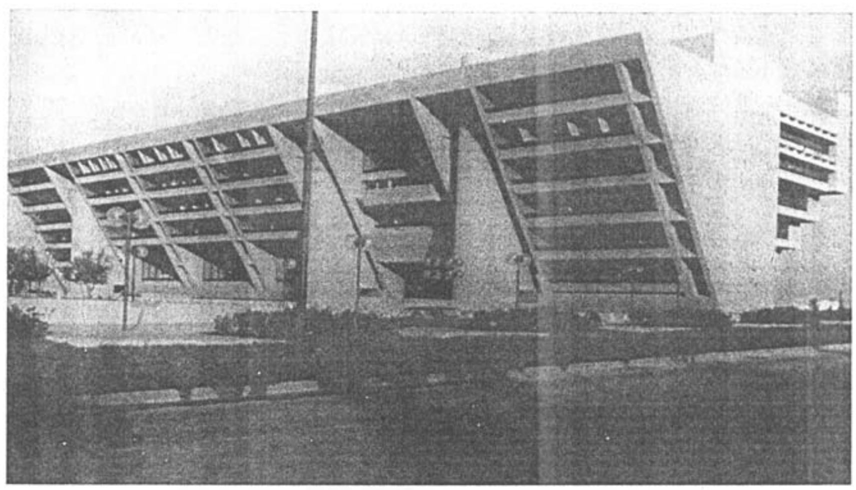

Figure 4.17: An example of inverted setback (Arnold, 1989, p.164)

4.1.5 Other Issues

4.1.5.1 Pounding (Battering or Hammering)

Two structures standing side by side may respond to seismic forces differently due to their different natural periods of vibration. Bumping to each other called ‘pounding’ (battering or hammering) between structures is a common occurrence, which may lead to failure.

Adequate separation with sufficient space between individual buildings is to be maintained to avoid the problem. The minimum separation distance depends on the height of the building and the flexibility of the building. The distance between adjoining buildings should exceed the sum of lateral displacements of each storey with an extra allowance (Coburn and Spence, 1992).

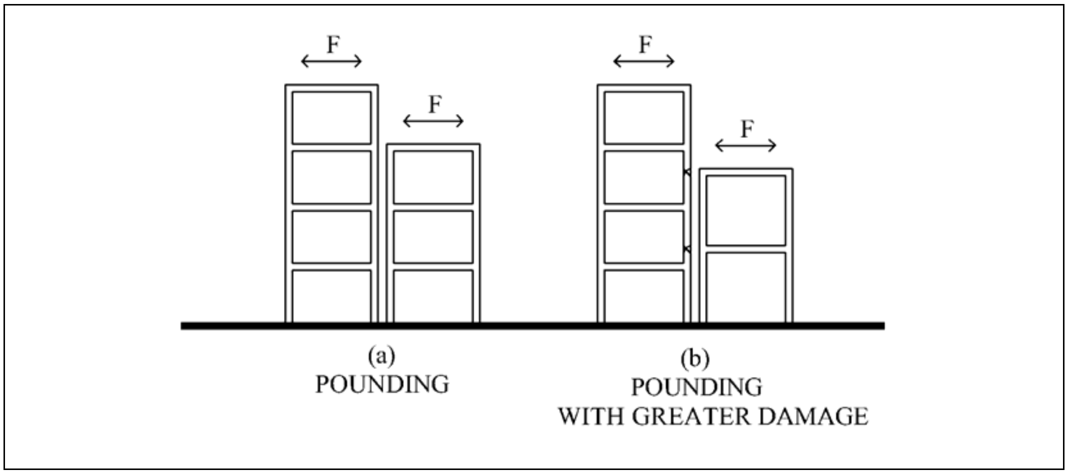

Figure 4.18: Pounding

If the structures are of similar height and their floor levels match, damage may be only in ‘apparent’ **(Figure 4.18a**). However, if the floors are at different levels, the floor of one structure may hit and damage the column of the adjacent structure causing structural damage and possibly collapse **(Figure 4.18b)** (Krinitzsky, Gould and Edinger, 1993). However, when the blocks with different heights are separated from each other with adequate seismic joints, they do not damage each other, although they experience different motions due to seismic forces and their varying stiffness and rigidities. According to the 1998 Turkish Earthquake Code, up to 6 m height, the separation width should be at least 30 mm. As the height of the building increases, 10 mm is to be added every 3 m height.

4.1.5.2 Weight of the Building

The earthquake force is directly proportional to mass (weight) of the building. Therefore, dead load constituting the building weight is a disadvantage in earthquakes. Ambrose and Vergun (1985) states that care should be exercised in developing the construction details and in choosing materials for the building in order to avoid creating unnecessary dead load, especially at upper levels in the building. Light materials for infill walls, floor and wall claddings should be preferred (Gönençen, 2000). A structure must be designed in order to resist earthquake forces, which is equal to 40 % of its total weight (Erman, 2002). On the other hand, dead load is useful for overturning resistance and it is necessary for the foundations that must anchor the building.

4.2 Structural System Configuration Issues

4.2.1 Structural System (Lateral Resistive System) Configuration in Plan

Attention should be paid to the arrangement of the lateral resistive elements. Regular configuration of structural system in plan mostly cannot be obtained due to the form of the site and the architectural planning requirements. Irregular arrangements of the elements make the seismic analyses difficult and the structure subject to torsional forces. Moreover, the coincidence of centers of mass and rigidity becomes hard to achieve (Bayülke, 2001).

4.2.1.1 Column, Shear Wall and Beam Configuration in Plan

The vertical elements of lateral resistive system configuration (columns and shear walls) should have these necessities in plan:

- The vertical structural elements should be arranged regularly on an axis system **(Figure 4.19a)**. Irregular and random arrangement should be avoided in order not to produce irregular and uncertain stresses due to seismic and other forces **(Figure 4.19b)** (Dowrick, 1987).
- It is necessary to locate equal number of elements on both axes **(Figure 4.19a)** (Tuna, 2000).
- The axes should have equal or close to equal intervals in order to achieve economy. If possible, the columns should be placed with regular spans **(Figure 4.19a)** (Zacek, 1999).
- In order to make seismic resistance and rigidity of the structure identical to each other for both directions, it is necessary to place columns on two directions **(Figure 4.19a)** (Bayülke, 2001).

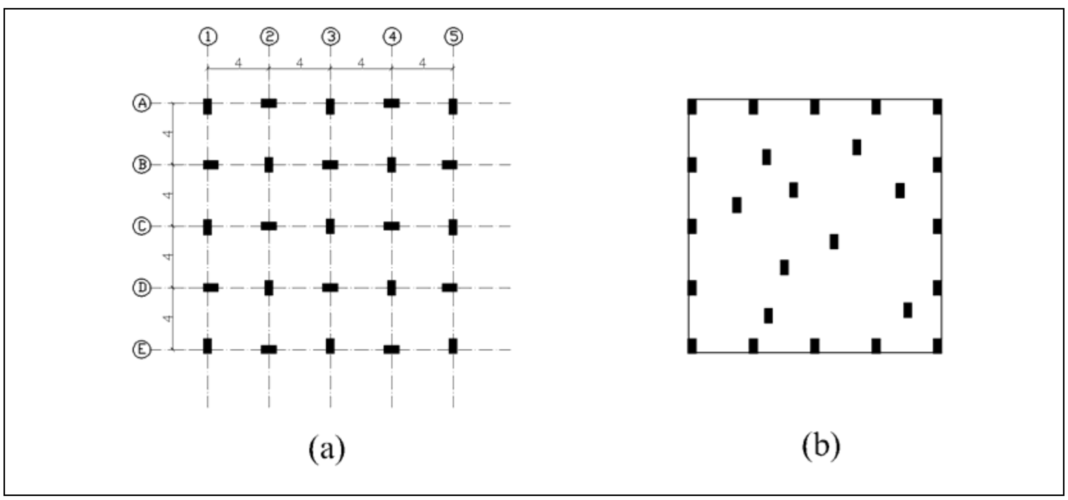

Figure 4.19: Regular and irregular vertical structural system configuration in plan

- The vertical structural elements must be stacked on top of each other. The lack of vertical structural elements at the lower stories should be avoided (Architectural Institute of Japan, 1970). If long and short sides of the columns for all stories do not coincide, eccentricity and torsion may be developed among stories (Bayülke, 2001).

- It is necessary to place the vertical structural elements perpendicular to the sides of the plan. As the most important damages occur on the columns and shear walls at the corners, it is needed to design L-shaped columns and shear walls on the corners **(Figure 4.20)** (Tuna, 2000).

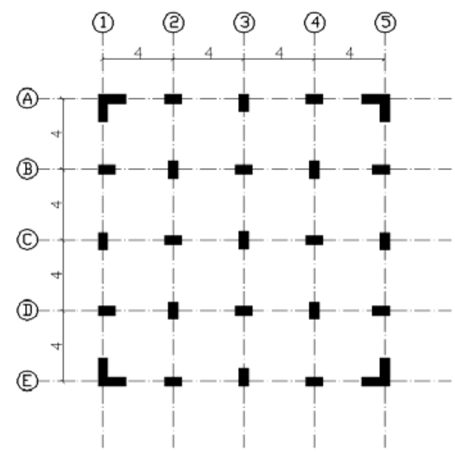

Figure 4.20: L-shaped columns and shear walls on the corners

- The vertical structural elements should be tied with beams on two directions to form a rectangular frame (Architectural Institute of Japan, 1970). If not, the distribution of seismic forces due to rigidities becomes difficult to achieve, so some of the elements are exposed to seismic forces more than the other ones **(Figure 4.21)** (Bayülke, 2001).
- It is necessary to make the sections of the columns and beams nearly same. As the seismic loads are distributed to the structural members proportional to their rigidities, the sections of elements should not change suddenly (Dowrick, 1987; Zacek, 1999).

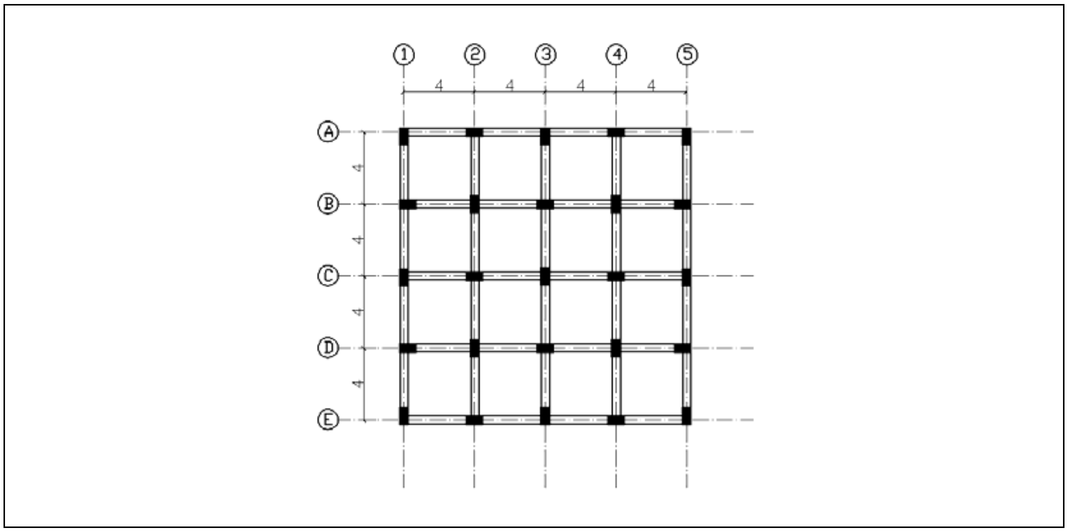

Figure 4.21: Rectangular frame with columns and beams

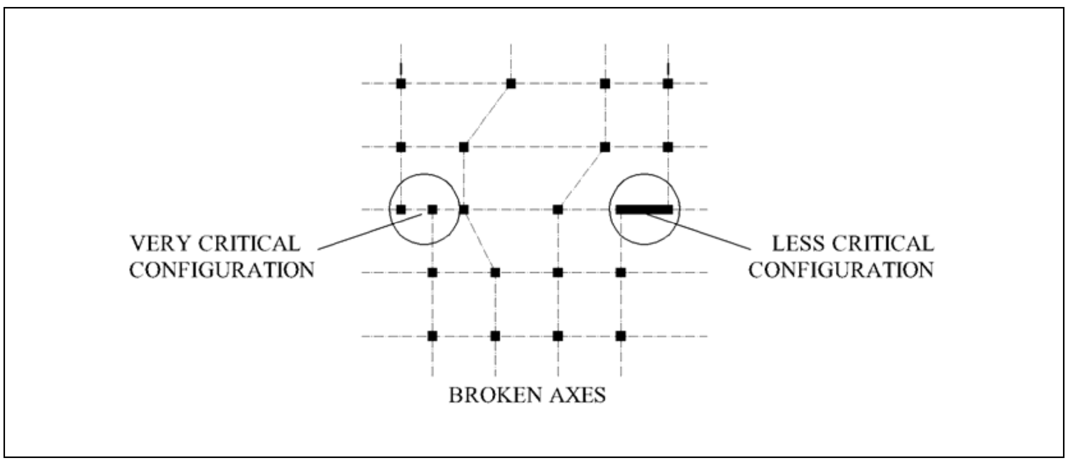

Figure 4.22: Frames with broken axes

- As beams with broken axes are less resistant to lateral forces, frame configurations with broken axes should be avoided due to excessive torsions that may occur **(Figure 4.22)** (Özmen, 2002).
- Being an engineering attribution, which plays an important role in seismic performance, design of the connections between elements is highly important

for the integrity of the whole lateral resistive system. It is necessary to detail the connections for an integrated, an interconnected, and a monolithic structure (Arnold, 1989).

- The centers of mass and rigidity should be coincided with the placement of vertical structural elements, if they do not, the eccentricity should not exceed 5 % of the building dimension **(Section 4.2.1.2)** (Tuna, 2000).

There exist additional necessities about shear walls. Shear walls are generally placed as the periphery of the staircases and lifts' shafts. However, if they are not symmetrically arranged in the building plan, torsional effects due to the eccentricity between the center of mass and center of rigidity become apparent (Bayülke, 2001).

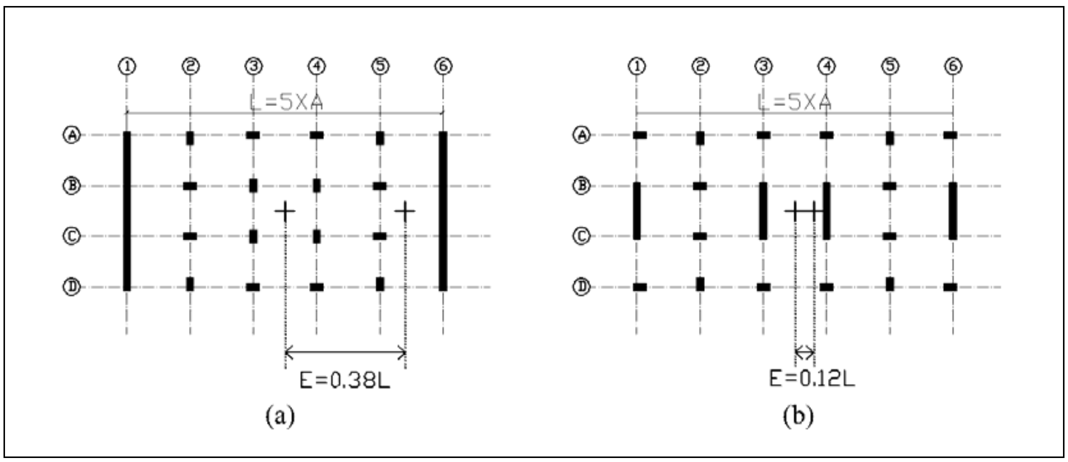

Figure 4.23: Eccentricity due to shear walls arrangement

It is more appropriate to distribute shear walls within the building in a symmetric manner. According to Uniform Building Code (UBC), which has been used in United States of America, minimum four shear walls are to be placed on both axes **(Figure 4.23b)**. This is why, if one of the shear walls at one side of the building has been damaged during earthquake, the center of rigidity does not change much. Hence, large torsional effects due to eccentricity are not produced. If two shear walls instead of four are arranged and one of them has been damaged, large displacement of center of rigidity and torsional effects may occur **(Figure 4.23a)** (Bayülke, 2001).

According to Bayülke (2001), two important principles for the arrangement of shear wall on building plan are:

- existences of many numbers of shear walls on plan,
- distribution of the shear walls within the building **(Figure 4.24)**.

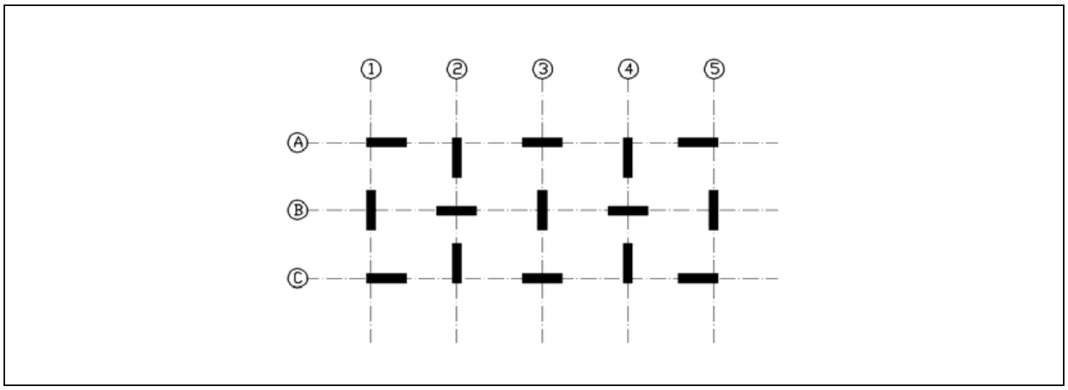

Figure 4.24: Distribution of the shear walls within the building

Beams should have these necessities:

- It is necessary to arrange beams at every storey, so that columns and beams form a rectangular frame **(Figure 4.21)** (Architectural Institute of Japan, 1970).
- If two beams are placed in a misleading manner, the section of the common column should be designed large enough. As an engineering attribution, the reinforcing of the column should be rearranged and accordingly increased. This is the effect of architectural design to the structural system design **(Figure 4.25)** (Bayülke, 2001).

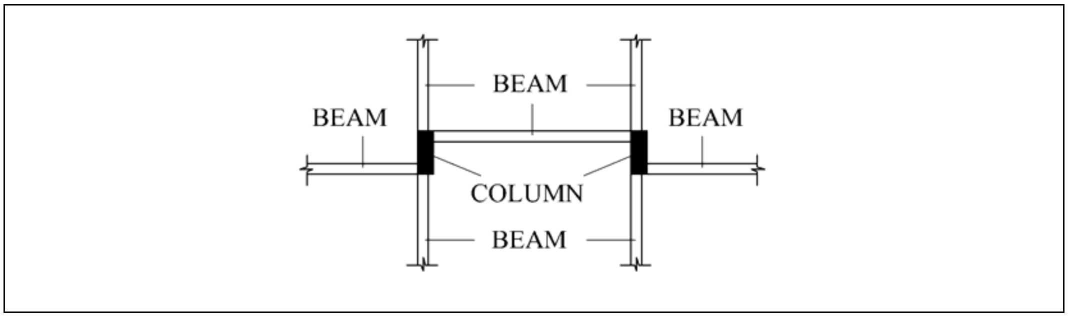

Figure 4.25: Beams with in a misleading manner

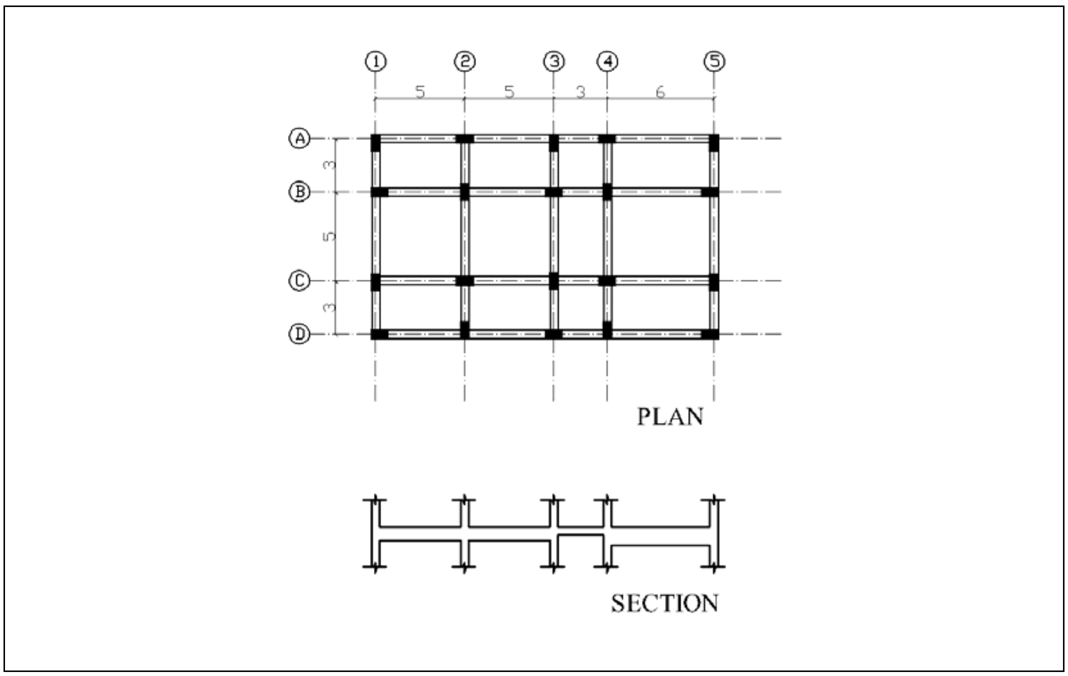

Figure 4.26: The depth of the beams due to spans

- The depth of the beams should be adjusted according to the span of the columns. If the columns are arranged with equal spans, the depths of the beams are necessary to be equal in order to avoid stress concentrations. If the spans are not equal, the more shallow beams should tie the short span columns in order not to cause the short span columns to become more rigid

(Figure 4.26) (Bayülke, 2001). However, in order to estimate the stresses due to the lateral loads properly, to design formwork economically and to detail the reinforcement conveniently, it is necessary to design equal spans and uniform beam sections (Özmen, 2002).

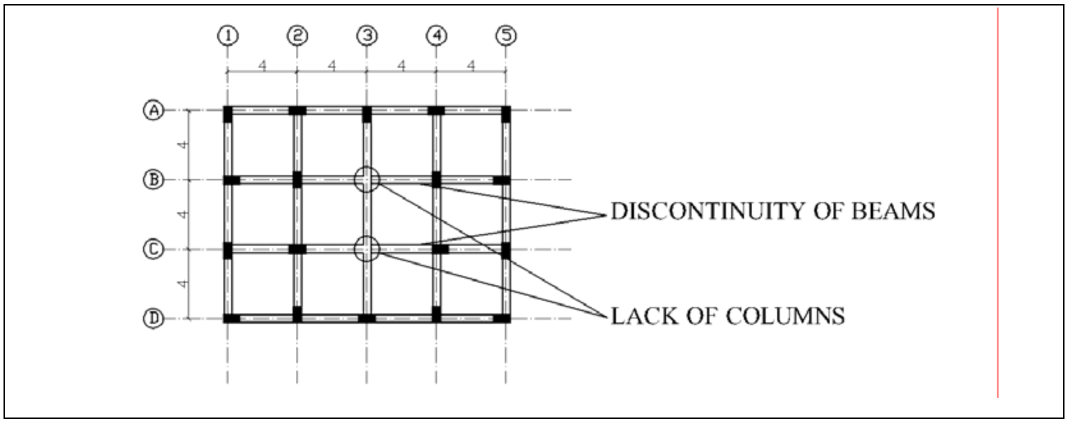

Figure 4.27: Irregularities about beams

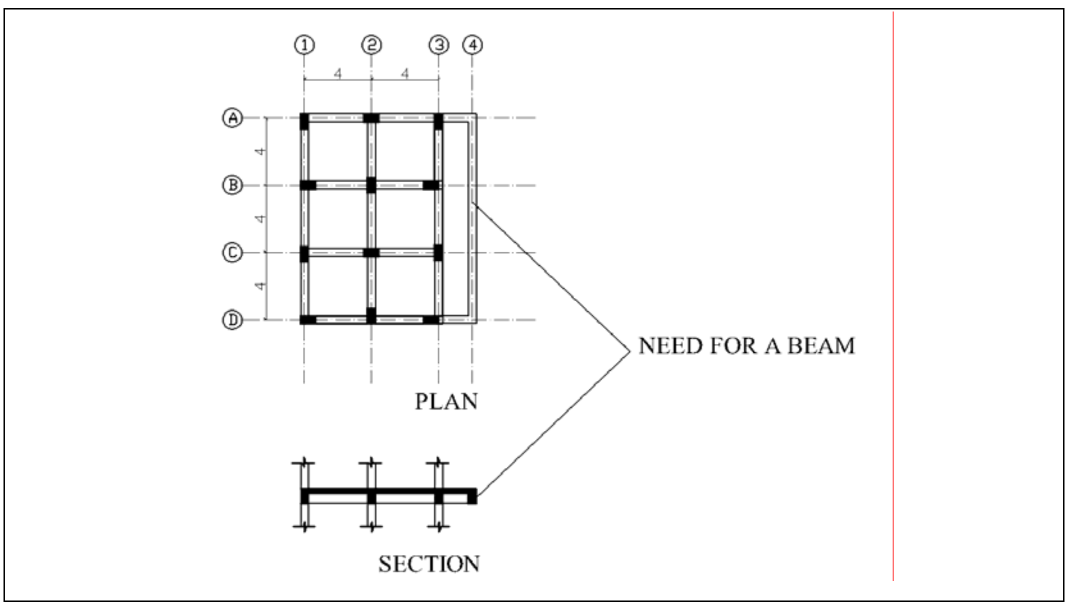

Figure 4.28: Beam for cantilever

- It is necessary to avoid beam-to-beam connections. The lack of column at the coincidence of the beams is undesirable **(Figure 4.27)** (Tuna, 2000).
- It is necessary to avoid non-continuous beams along the axis **(Figure 4.27)** (Dowrick, 1987).
- Beams should be placed at the edges of the cantilevers **(Figure 4.28)** (Tuna, 2000).

4.2.1.2 Torsional Rigidity

The center of building mass is generally considered as the geometrical center of the building and the center of rigidity is considered as the center of vertical elements of the structural system. The center of rigidity of a building should coincide with the center of mass **(Figure 4.29).**

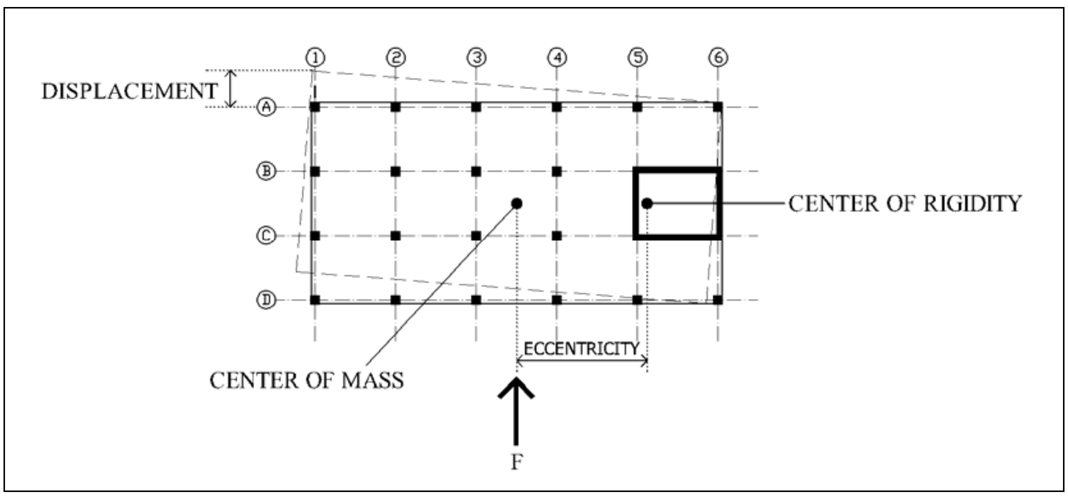

Figure 4.29: Torsional response

When the center of a building mass does not coincide with the center of rigidity, torsion and stress concentrations occur in the building when it is subjected to seismic loads. Eccentricity between the centers makes the building rotate due to seismic forces. In order to avoid torsional deformation, it is desirable to have symmetry both in the building configuration and structure. The vertical structural elements of the lateral resistive system should be arranged in order to approach the centers of mass and rigidity to each other and in order to produce high resistance to torsional effects on the building (Ambrose and Vergun, 1985; Wakabayashi, 1986).

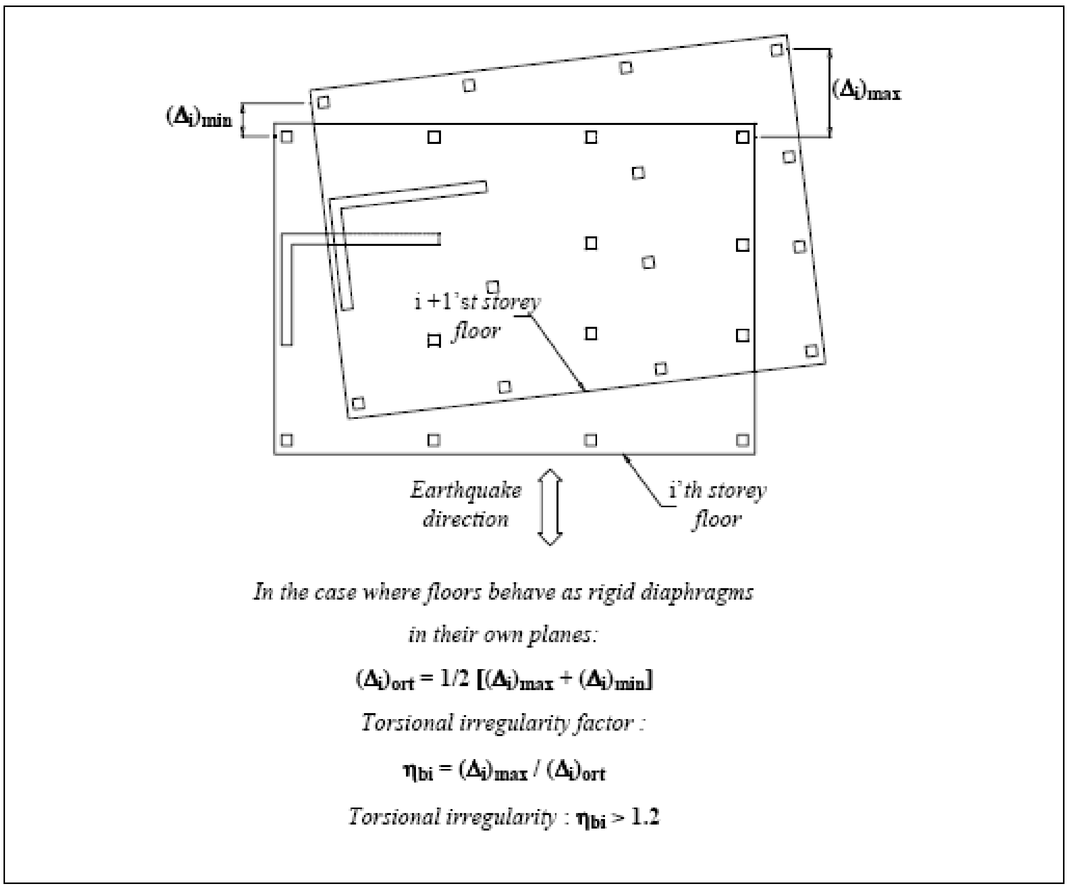

Figure 4.30: Torsional Irregularity (Turkish Earthquake Code, 1998, p.8)

When the vertical structural elements of the lateral resistive system of a building are not symmetrically distributed, the less rigid portion of the building makes a greater displacement than the more rigid portion. The situation is stated in the 1998 Turkish Earthquake Code as A1-Torsional Irregularity and as follows:

A1 – Torsional Irregularity:
The case where Torsional Irregularity Factor, which is defined for any of the two orthogonal earthquake directions as the ratio of the maximum storey drift at any storey to the average storey drift at the same storey in the same direction, is greater than 1.2.
[Δi = (Δi) max / (Δi) ort > 1.2]

4.2.1.3 Diaphragm Configuration

Diaphragms, which transfer forces between vertical structural elements, are needed to connect them and to make them resist to the seismic forces as one body. Architectural Institute of Japan (1970) states that they behave like columns when the lateral forces are considered as the horizontal forces.

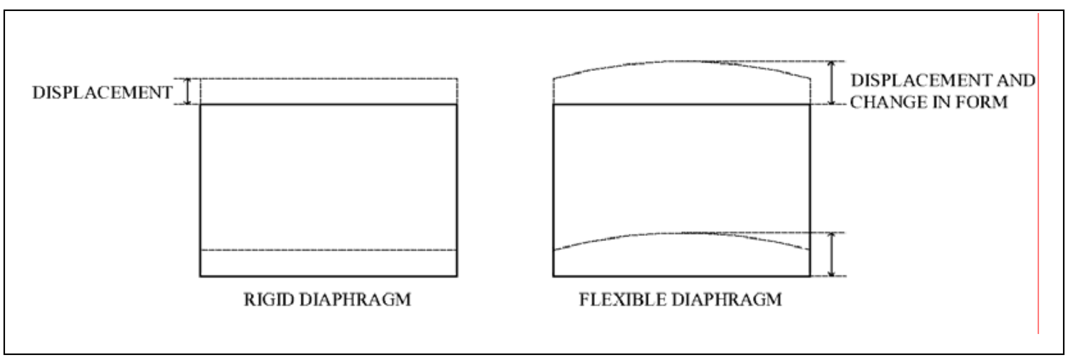

Figure 4.31: Behaviour of the diaphragm under earthquake loading

A diaphragm may act either in a rigid or a flexible manner. Rigid diaphragm moves as a rigid body without deformations due to lateral forces, whereas the form of the flexible diaphragm tends to change with the displacement **(Figure 4.31)** (Bayülke, 2001). According to Zacek (1999), the rigidity of the diaphragms depends on:

- form and size (Long and narrow diaphragms are more flexible. Damages due to stress concentrations are seen at the re-entrant corners of the diaphragms.),
- material,
- connections of the structural elements,
- penetration (opening).

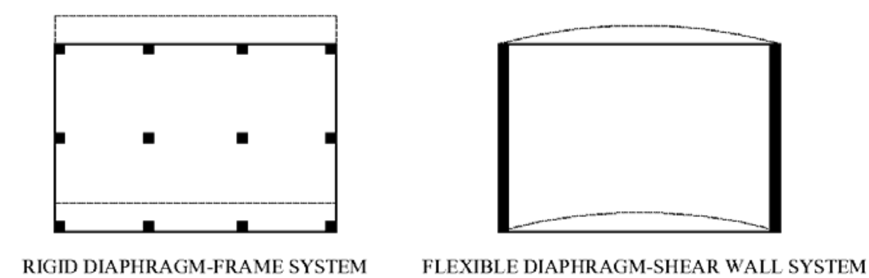

Figure 4.32: Behaviour of the diaphragm according to the structural system

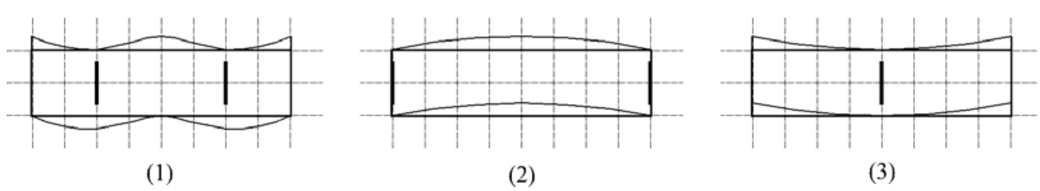

Figure 4.33: Behaviour of the diaphragm according to the locations of shear walls

Sometimes, diaphragm, which ties the columns, may behave as a rigid plane whereas diaphragm with same property, which ties the shear walls, may behave as a flexible one **(Figure 4.32)**. The rigidity of diaphragms may also change according to the locations of shear walls **(Figure 4.33)** (Bayülke, 2001).

Architectural requirements such as necessities for vertical traffic within a multi-storey building, visual integration of stories, and other purposes result in a variety of diaphragm penetrations such as staircases, elevators, atriums, duct shafts, skylights, and so on. The size, location, and even shape of the penetrations are critical to the effectiveness of the diaphragm. Diaphragm penetration and their geometrical irregularities weaken the load carrying capacity and the lateral rigidity leading to torsion and stress concentration. For instance, the logical planning location for an elevator in an L-shaped building is at the notch of the building, which is also the area of seismic stress concentration (Arnold, 1989).

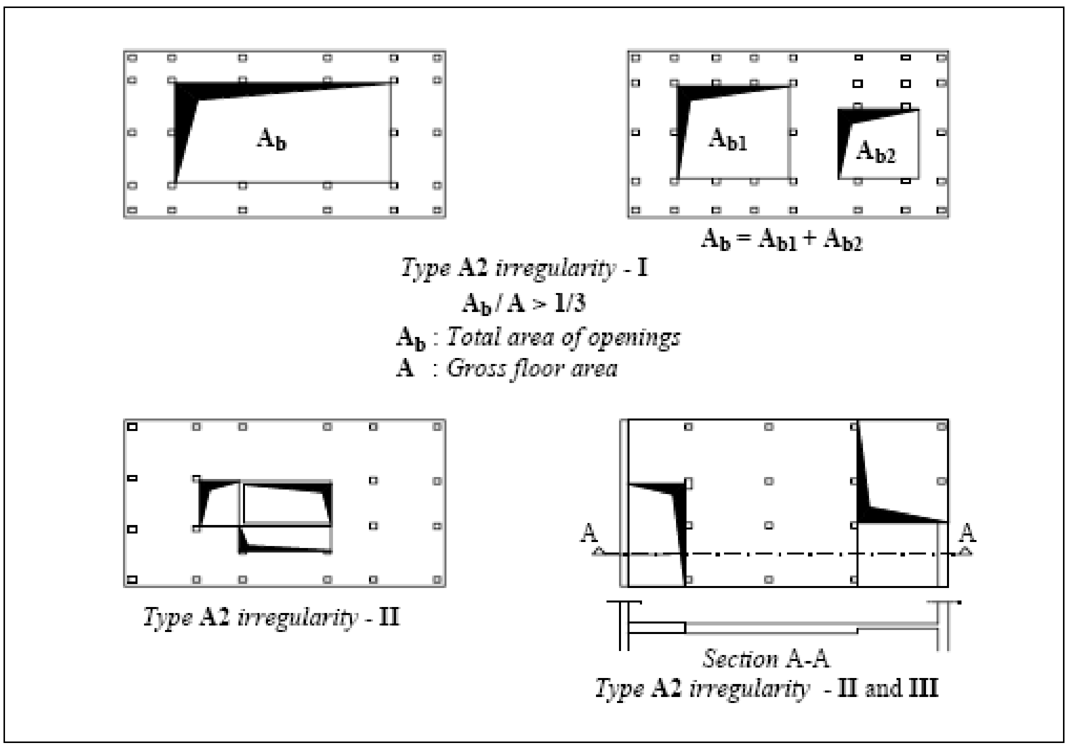

Figure 4.34: A2 Floor Discontinuity (Turkish Earthquake Code, 1998, p.9)

According to the 1998 Turkish Earthquake Code, the problems of diaphragm penetrations are stated as A2 Floor Discontinuity and as follows:

> *A2 – Floor Discontinuities:*
> *In any floor;*
> ***I -** The case where the total area of the openings including those of stairs and elevator shafts exceeds 1/3 of the gross floor area,*
> ***II –** The cases where local floor openings make it difficult the safe transfer of seismic loads to vertical structural elements,*
> ***III –** The cases of abrupt reductions in the in-plane stiffness and strength of floors.*

As Arnold (1989) declares, “failures specifically due to diaphragm design are difficult to identify, but there is general agreement that poor diaphragm layout is a potential contributor to failure” (p.158). If the relative size of the penetration in a diaphragm is a reasonable one, placement of reinforcement for the edges and corners of the opening and adequate diaphragm width at the opening may be sufficient for the integrity of the continuous diaphragm. However, if the penetration in a diaphragm is quite large, the diaphragm should be separated into small and regular parts for maintaining the continuity of the whole diaphragm (Ambrose and Vergun, 1985).

4.2.1.4 Axis System

It is necessary to place the vertical structural elements parallel to the major orthogonal axes of the structural system. If the columns are arranged and beams are tied with an angle different from 90, building exercises poor seismic performance with its nonparallel axes system. In this condition, there exists a high probability of torsional forces under earthquake motion, because the centers of mass and resistance cannot coincide for all directions of earthquake motion. In this case, the building should be separated into simple and regular forms with seismic joints in order to reduce the effects of torsion.

The 1998 Turkish Earthquake Code describes the situation as an irregularity called A4 – Nonparallel Axes of Structural Elements and as follows:

> *A4 – Nonparallel Axes of Structural Elements:*
> *The cases where the principal axes of vertical structural elements in plan are not parallel to the orthogonal earthquake directions considered.*

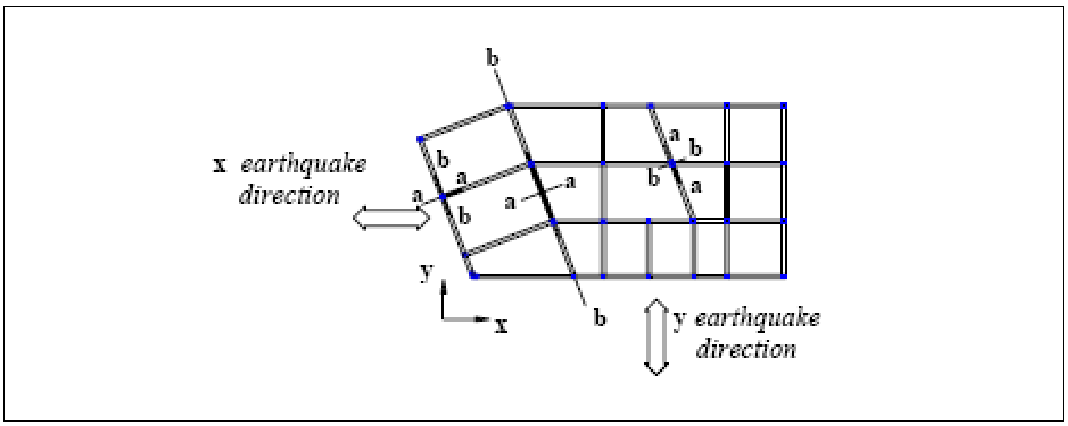

Figure 4.35: Nonparallel Axes of Structural Elements
(Turkish Earthquake Code, 1998, p.9)

A characteristic form of 'nonparallel axes' condition is the triangular or wedge-shaped building that results from street intersections at an acute angle. The narrower portions of the building tend to be more flexible than the wider ones, which increase the tendency to torsion **(Figure 4.36)** (Arnold, 1989).

Figure 4.36: Example for a wedge-shaped building (Arnold, 1989, p.157)

4.2.1.5 Dimension and Density of Structural Elements

The resistance of the structural system depends on the sections of the members. As the section of a reinforced concrete structure member increases, its earthquake resistance increases (Erman, 2002). Dowrick (1987) states that reinforced concrete columns and beams should have nearly the same or similar width. This promotes good detailing and helps the transfer of moments and shears through the connection of the members. Very wide or shallow beams may fail near the connections of normal-sized columns **(Section 4.2.2.4)**.

The total area of the vertical structural elements divided by the gross floor area is defined as structural plan density. There is an enormous reduction of structural plan density of modern buildings when it is compared to historical ones. The size and density of structural elements in the buildings of early centuries are strikingly greater than in today's building **(Figure 4.37).** For instance, the structural plan density of a typical 10-20 story steel frame building is 1 %, frame-shear wall design is 2 %, whereas the structural plan density of a historical building (for example: Taj Mahal) is 50 % (Arnold, 1989).

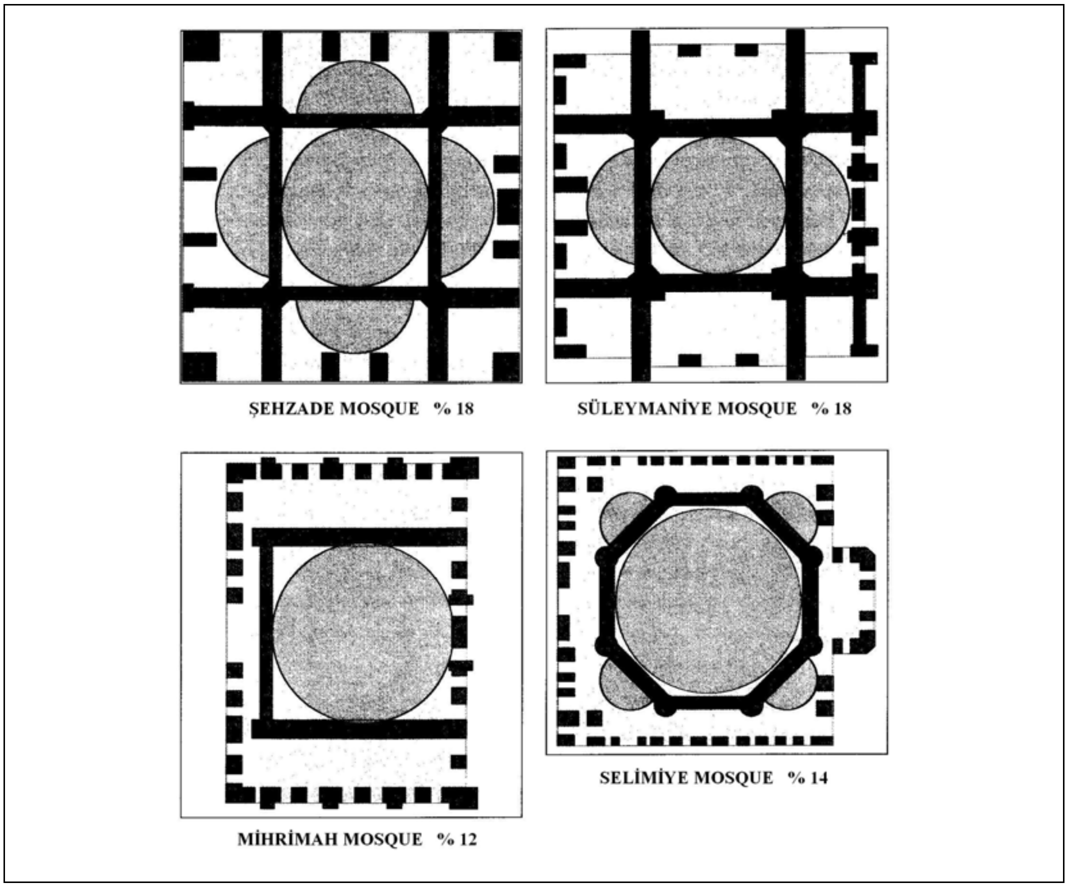

Figure 4.37: The structural plan density of historical buildings (Ünay, 2002, p.73)

Earthquake forces are generally greatest at the ground level. The bottom story is required to carry its own lateral load in addition to the shear forces of all the stories above. The most efficient seismic configuration is the need of greatest intensity of vertical structural elements at the ground floor, whereas programmatic and aesthetic criteria often demand the removal of them as much as possible (Arnold, 1989).

4.2.2 Structural System (Lateral Resistive System) Configuration in Vertical

Uniformity in the distribution of masses, rigidities, and strength is also desirable in the vertical direction of the building. The structural elements of lateral resistive system configuration (columns and shear walls) should have these necessities in vertical in order to make structures more easily analysed and avoid undesirable stress concentrations and torsions:

- All vertical elements of lateral resistive system should be continuous throughout the building height, from roof to foundation **(Section 4.2.2.3)**. Non-existence of elements on the ground floor or the interruption of them somewhere in the building storey is too detrimental in terms of lateral forces (Bayülke, 2001).
- It is necessary to make all the column heights equal for a story (Zacek, 1999).
- It is necessary to make the rigidity of the stories similar. At the upper stories, the decrease in rigidity can be acceptable which makes the vibration of the building decrease (Zacek, 1999).
- Homogeny in buildings must be present. As all the structural system have their own dynamic responses to the earthquake forces due to their weight, rigidity, and geometry, using different structural systems together may cause failures (Zacek, 1999).

Buildings with shear wall systems generally performed well during the 7.4 magnitude of Kocaeli Earthquake on August 17, 1999. Storey collapses were not observed in buildings containing shear walls, but it should be noted that shear walls were not widely used in the epicentral region. On the other hand, buildings with reinforced concrete frame systems behaved poorly during the earthquake. According to official estimates, more than 20.000 buildings with frame systems collapsed and many suffered from moderate to severe damage (Sezen, Whittaker, Elwood, and Mosalam, 2003).

There exist additional necessities about the shear walls. The inclined bases of the shear walls lead to decrease in rigidity of the ground floor. Moreover, the deformations of the bases become too complicated **(Figure 4.38)** (Bayülke, 2001).

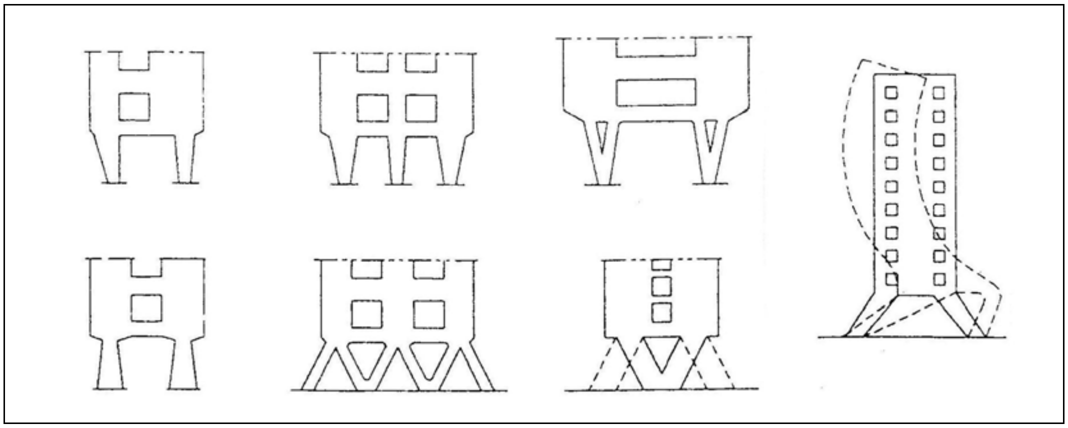

Figure 4.38: The inclined base of the shear walls and its behaviour due to earthquake forces (Bayülke, 2001, p.137)

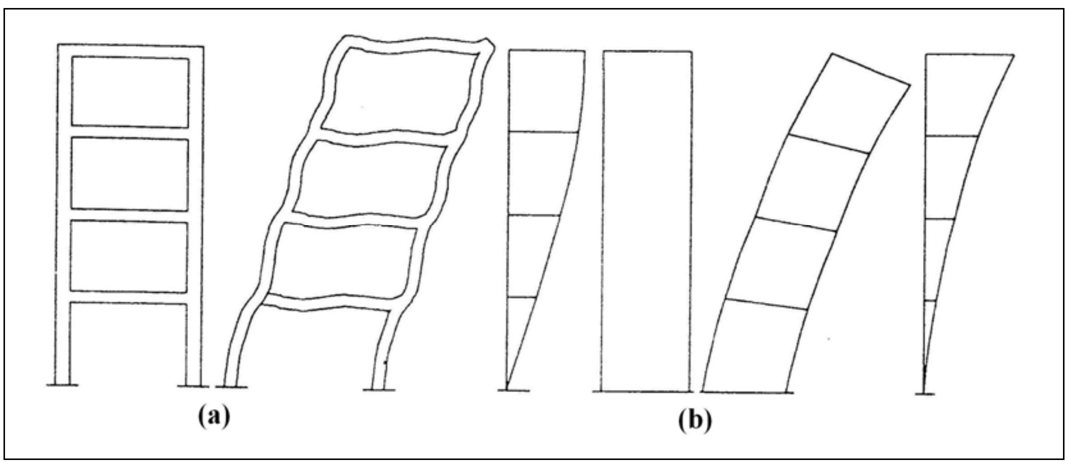

Figure 4.39: The deformations of frame system (a) and the shear wall system (b) (Bayülke, 2001, p.138)

The deformations, due to lateral forces, of the shear wall system and frame system of a building are different from each other. The lateral deflections of the shear walls increase as the building grows up, whereas the lateral deflections of the frames and successive deflections among stories decrease as the building grows up. Shear walls limit the lateral deflection of the frames at lower stories, whereas frame systems limit the lateral deflection of the shear walls at upper stories **(Figure 4.39)** (Bayülke, 2001). On the other hand, in 1999 Kocaeli Earthquake, although the shear wall in a dual wall-frame building was likely sufficiently stiff to protect the frame, failure of the first storey columns was observed (Sezen, Whittaker, Elwood, and Mosalam, 2003)

4.2.2.1 Soft Storey

Any abrupt change in lateral stiffness results in deformation and stress in a building, which is subjected to earthquake loads (Ambrose and Vergun, 1985). A building with soft story is defined as a building with a stiff and a rigid superstructure placed on top of an open and a flexible floor (Lagorio, 1990). The condition is most critical when it occurs at the ground floor, because the loads are generally greatest at the ground floor level (Arnold, 1989).

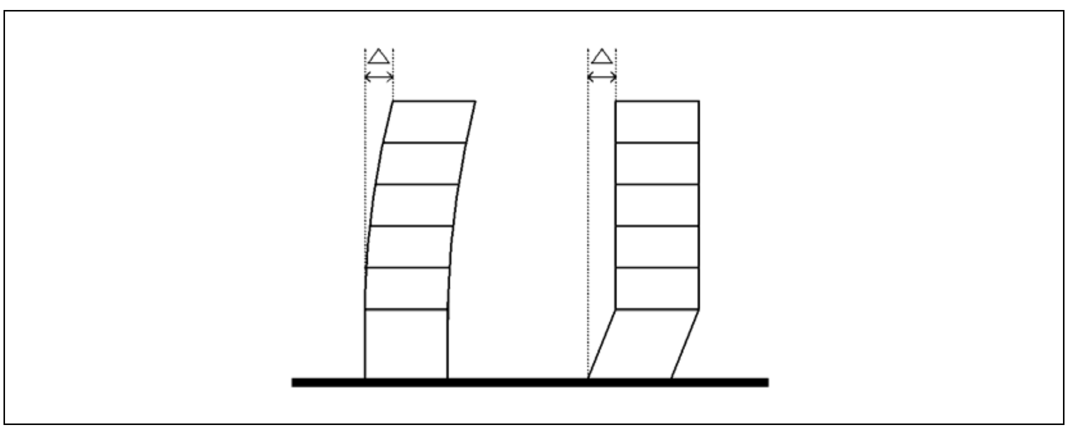

Figure 4.40: The soft storey formation

If all stories are approximately equal in strength and stiffness, the entire building deflection under earthquake forces is distributed approximately equally to each story. If the ground floor is significantly less strong or more flexible, a large portion of the total building deflection tends to concentrate there, with consequent concentration of stresses at the upper floor connections **(Figure 4.40)** (Arnold, 1989). Unless the connection between the open ground floor and the stiffer upper floors has been adequately designed to absorb the stress concentrations and to allow for the transition of forces to the vertical structural elements at the lower floor, failure may occur (Lagorio, 1990).

According to the 1998 Turkish Earthquake Code, soft storey irregularity is defined as follows:

> *B2 – Interstorey Stiffness Irregularity (Soft Storey):*
> *The case where in each of the two orthogonal earthquake directions, Stiffness Irregularity Factor, which is defined as the ratio of the average storey drift at any storey to the average storey drift at the storey immediately above, is greater than 1.5.*
> [$\eta_{ki} = (\Delta_i)_{avr} / (\Delta_{i+1})_{avr} > 1.5$]

These are the major causes of the soft-story formation. The soft storey formation is observed:

- when the ground story of a building is significantly taller than upper floors. This results in less stiffness and more deflection in the ground story **(Figure 4.41a)**.
- when there exists an abrupt change of stiffness at the upper story, although the story heights remain approximately equal. This is caused primarily by material choice, for example, the use of heavy precast concrete elements above an open ground story **(Figure 4.41b)**. Tuna (2000) states that greater dimensions of columns and beams at the upper floors, when compared to the lower ones, and infill walls at the upper floor, which are not taken into

consideration during earthquake analyses, also increase the rigidity of the upper floors and result in soft story formation.

- when the vertical structural elements do not continue down to the foundations and interrupt at any floor level, when there exists discontinuous load paths **(Figure 4.41c)**. Thus, it also creates change of stiffness (Arnold, 1989).

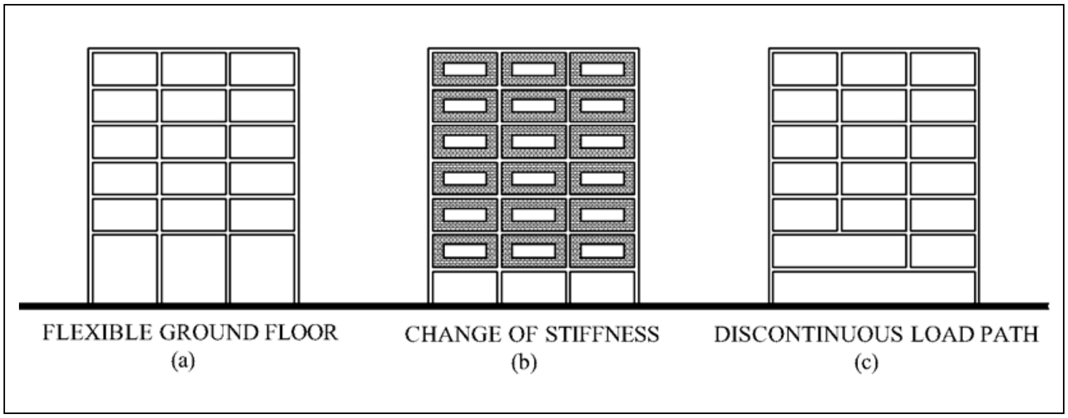

Figure 4.41: The causes of soft storey formation

Many of the collapses during the 1999 Kocaeli earthquake, are attributed to the formation of soft first stories that formed due to the differences in frame system and infill wall geometry between the first and upper stories. Many of the buildings were constructed with hollow clay tile infill walls, only above the first storey in order to allow for commercial space on the ground level **(Figure 4.41b)**. Such an arrangement of infill walls created stiffness discontinuities in these buildings, which may have contributed to their collapses by concentrating the drift demands in the first storey. Generally, these walls are almost unreinforced and they adjoin the frame members without being tied to them (Sezen, Whittaker, Elwood, and Mosalam, 2003)

It is interesting that, while the existence and non-existence of soft story formation is equally distributed among older and three-storey buildings, taller buildings with soft stories were about 70 %, and the seven-storey buildings were observed as entirely having this property (Yakut, Gülkan, Bakır and Yılmaz, 2005).

Many multi-story buildings of soft story types commonly occur on ground floor levels. It becomes an architectural solution to programmatic requirements. Generally, the ground floor is designed with as much openness as possible in order to attract the pedestrian into the interior. By the way, it often meets urban design needs. Automobile showrooms, department stores with their display spaces, and commercial exhibition centers are typical examples that require an exterior treatment of open ground floor (Lagorio, 1990). Moreover, taller ground floor often has functional purposes, when large spaces such as meeting rooms, banking halls, restaurants, ballrooms, and so on must be provided at ground floor level (Arnold, 1989; Krinitzsky, Gould and Edinger, 1993).

Ambrose and Vergun (1985) state that reduction of the soft story effect can be possible. The remedies for soft storey are:

- to brace some of the openings **(Figure 4.42a)**,
- to keep the building plan periphery open, while providing a rigidly braced interior **(Figure 4.42b)**,
- to increase the number or the stiffness of the ground floor column **(Figure 4.42c)**,
- to use tapered or arched forms for the ground floor **(Figure 4.42d)**,
- to develop a rigid ground story as an upward extension of heavy foundation structure **(Figure 4.42e)**,
- to equalize the rigidity of the stories by separating the non-structural elements from the structural ones or using light and less rigid non-structural elements for infill walls and exterior claddings **(Figure 4.42f)** (Zacek, 1999).

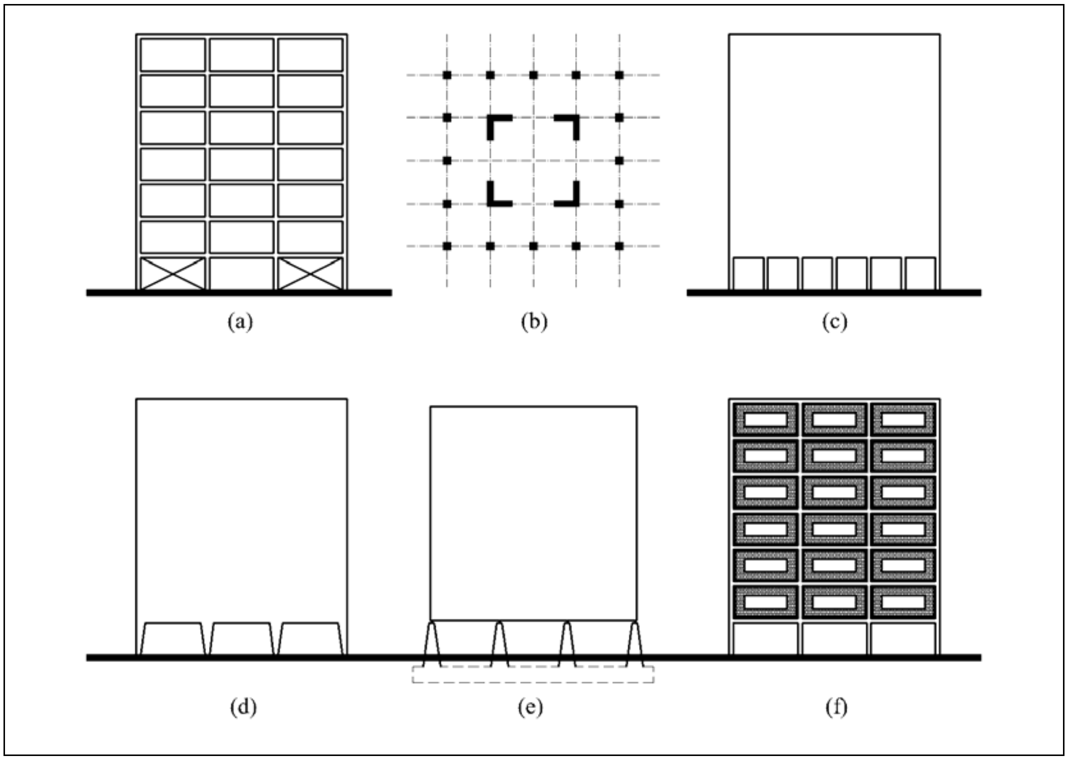

Figure 4.42: The remedies of soft storey formation

As the aim of seismic design is to form a system, which is able to dissipate earthquake energy and the effects of the lateral deformation on the response of the entire building, the soft story is actually a method for major energy absorption, which could be a positive factor in some situations. However, the major stress concentrations and deformations must be carefully provided for and true dynamic analyses are certainly indicated (Ambrose and Vergun, 1985; Mezzi, Parducci and Verducci, 2004).

4.2.2.2 Weak Story

Any abrupt change in lateral strength results in deformation and stress in a building, which is subjected to earthquake loads. Weak story is described as a discontinuity in capacity. It is essential to understand the distinction between a soft story and a weak story, although it is possible for a single story to be both. The soft story is based on stiffness or simply the relative resistance to lateral deformation or relative displacement (drift) of a story. The weak story is based on strength in terms of force resistance (static) or energy capacity (dynamics) (Ambrose and Vergun, 1985).

The required ratio of strength is stated in the 1998 Turkish Earthquake Code as follows:

> *B1 – Interstorey Strength Irregularity (Weak Storey):*
> *In reinforced concrete buildings, the case where in each of the orthogonal earthquake directions, Strength Irregularity Factor which is defined as the ratio of the effective shear area of any storey to the effective shear area of the storey immediately above, is less than 0.80.*
> *[$\eta ci = (\sum Ae)\ i / (\sum Ae)\ i+1 < 0.80$]*
> *Definition of effective shear area in any storey:*
> $\sum Ae = \sum Aw + \sum Ag + 0.15 \sum Ak$

4.2.2.3 Discontinuity of Structural Elements

Forces applied to buildings must travel from their points of origin through the whole system and into the ground, in the design for lateral loads. The force paths must be complete. Where there are interruptions in the normal flow of the forces, problems occur. In a multi-story building, columns and shear walls must be stacked on top of each other. If a column is removed in a lower story, a major problem is created, requiring the use of a heavy transfer girder or other device to deal with the discontinuity **(Figure 4.43a-b)** (Ambrose and Vergun, 1985).

The 1998 Turkish Earthquake Code describes the irregularity as follows:

B3 - Discontinuity of Vertical Structural Elements:
The cases where vertical structural elements (columns or structural walls) are removed at some stories and supported by beams or gusseted columns underneath, or the structural walls of upper stories are supported by columns or beams underneath.

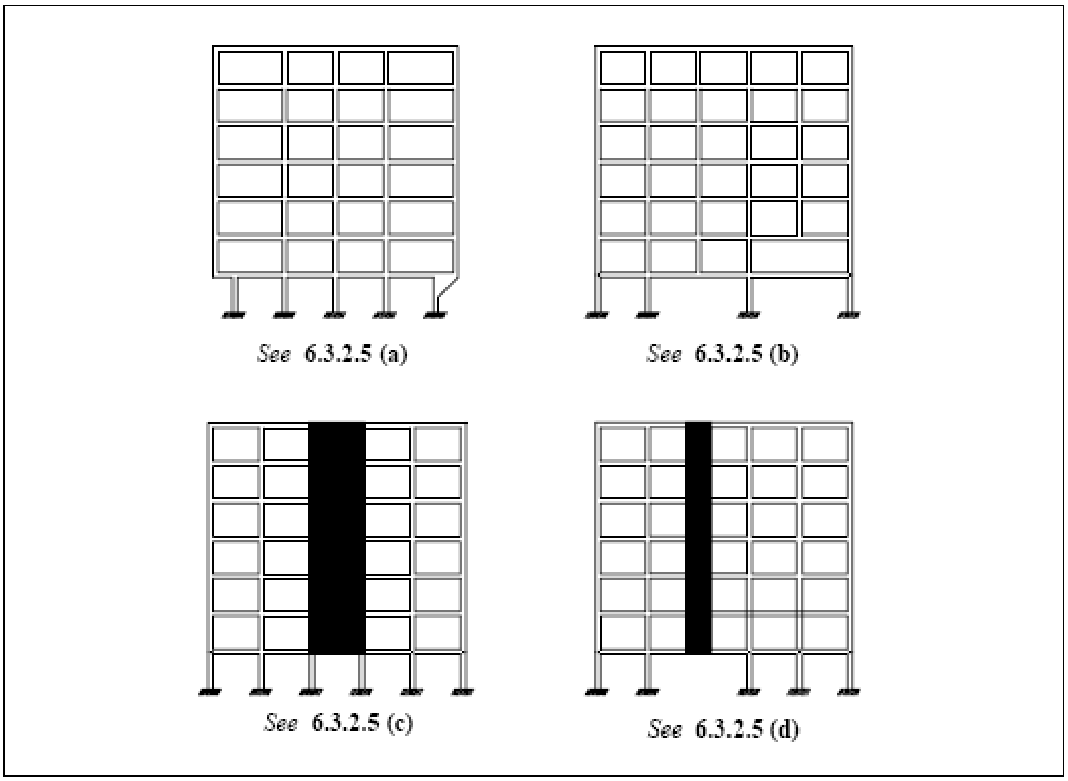

Figure 4.43: Discontinuity of vertical structural elements
(Turkish Earthquake Code, 1998, p.10)
(Discontinuity of columns: (a) column resting on a cantilever beam and a gusset, (b) column resting on a beam; Discontinuity of shear walls: (c) shear wall resting on columns, (d) shear wall resting on a beam)

Overturning effect may come to existence as a problem, if shear wall does not continue down to its foundation, if it is interrupted in a multi-story building **(Figure 4.43c-d)**. For a solution, individual panels of X-bracing are used sufficiently similar in function to the individual panels of the shear wall (Ambrose and Vergun, 1985).

4.2.2.4 Strong Beam-Weak Column Formation

The requirement is that columns should be stiffer than the beams **(Figure 4.44b)**. If this is the case, the beams fail before columns under severe seismic forces, limiting damage to the area supported by the beam and enabling the beams to dissipate and absorb seismic energy. On the contrary, if the columns are significantly weaker than the beams **(Figure 4.44a)**, they attract greater forces than deep and stiff beams. Hence, the columns begin to deform and buckle, and then fail first. Failure tends to occur very rapidly under lateral loads that may quickly lead to total collapse (Arnold, 1989; Coburn and Spence, 1992).

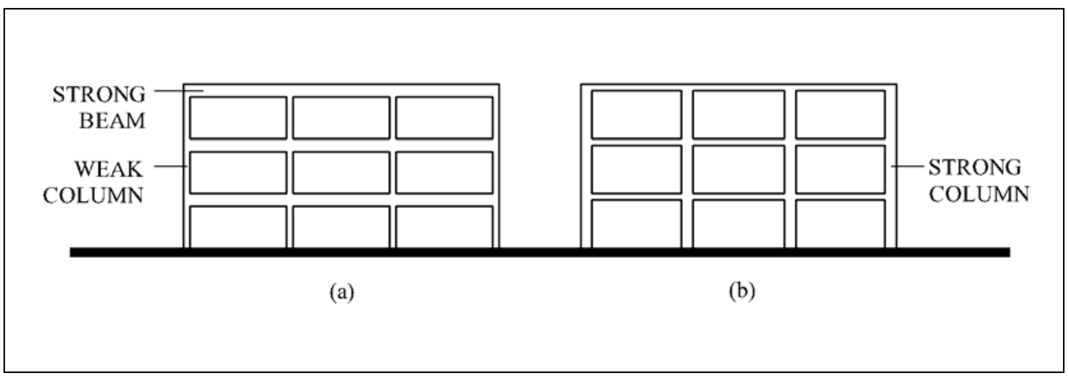

Figure 4.44: The weak-column, strong-beam formation

The general solution is to provide a detailed seismic design carefully to the architectural requirements. The weak-column, strong-beam condition can be avoided by making deep beams isolate from the columns (Arnold, 1989).

4.2.2.5 Short Column Effect

If both long and short columns exist in the same story, instead of distributing the loads equally among all of the columns, the columns experience different shear forces due to their height differences. The lateral loads are passed from the longer and more flexible columns to the shorter and the stiffer ones, and concentrated on the short columns. As short columns are not designed for overloading, failure occurs along the line of short columns before the longer and more flexible ones, which simply deflect without cracking (Lagorio, 1990).

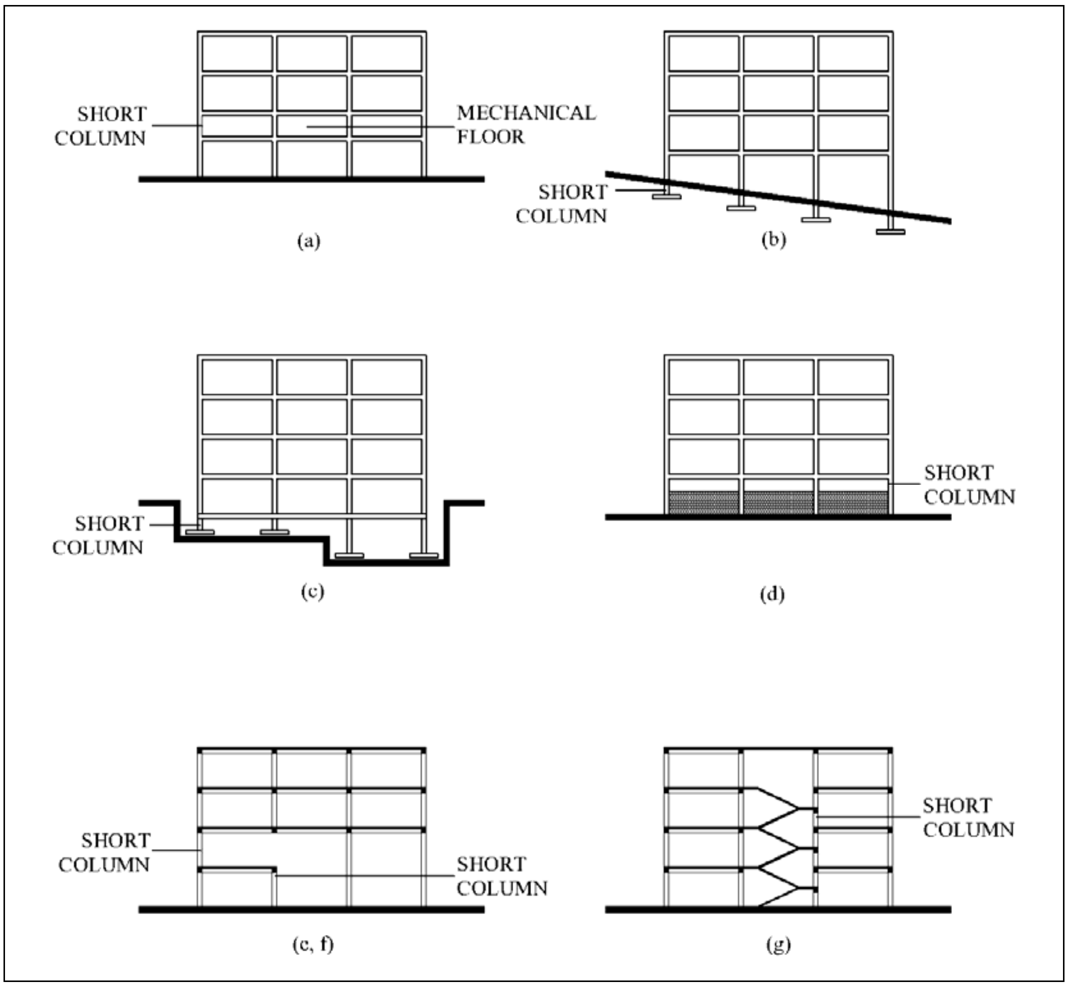

Figure 4.45: The reasons of short column formation

Some architectural considerations may result in short column formations. These are:

- mechanical storey designed with less height when compared to the other stories **(Figure 4.45a)**,
- hillside sites **(Figure 4.45b)**,
- graded foundation level **(Figure 4.45c)**,
- high strip windows formed by infilling some portions of frames with non-structural but stiff material **(Figure 4.45d)**,
- columns with different heights on facades of a building such as raising a portion of the building off the ground on tall pilotis while leaving other portions on shorter column **(Figure 4.45e)** (Arnold, 1989),
- mezzanine or loft resulting in stiffening some of the columns while leaving others at their full heights **(Figure 4.45f)** (Arnold, 1989),
- landing of the staircases placed at a level between the story height, generally half of it **(Figure 4.45g)**.

On the other hand, there exist solutions in order to avoid short column formation. These are:

- It is necessary to keep the heights of columns around a facade approximately equal. If the unequal heights of the columns are needed, horizontal bracing can be inverted to equalize the stiffness of the columns of varying height. Another solution is to obtain the visual effect of unequal heights of the columns with the help of non-structural architectural elements where the column heights remain same, actually **(Figure 4.46a)** (Zacek, 1999).
- Short columns may turn into a shear wall **(Figure 4.46b)**.
- Non-structural walls should be isolated from columns by developing architectural details (Arnold, 1989). Placement of elastic or flexible material in between the infill walls and the structural members is necessary to obtain independent displacement of the frames system from the infill walls **(Section 4.3.1) (Figure 4.46c)** (Gönençen, 2000).
- As an engineering attribution, proper arrangement of reinforcing for short column solves the problem.

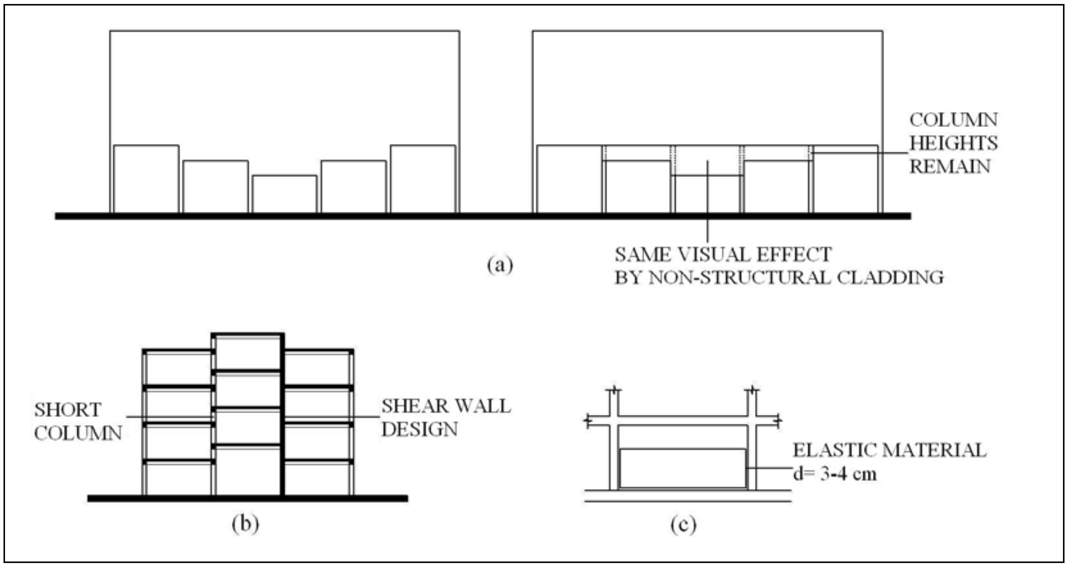

Figure 4.46: The solutions for short column formation

An architect should be aware of the reasons of the short column formation. Therefore, coordination between the architect and the structural engineer is important and is needed to avoid the problem in the architectural design process (Gönençen, 2000).

4.2.2.6 Foundation Configuration

The soil condition, in which the seismic waves radiate, is an important consideration. Rocky and strong soil transmits seismic waves as how they are, without making them larger, whereas soft soil transmits seismic waves with an increase in its effect. Therefore, it is very important to settle the structure on an appropriate soil and accordingly to chose an appropriate foundation system (Erman, 2002).

An integral foundation system should tie together all vertical structural elements in both principal directions (Paulay and Priestley, 1992). The footings are classified as isolated (independent) footing, continuous footing, raft (mat) foundation, and so on.

Generally, isolated footings are used below columns and continuous footings are used below shear walls. The raft foundation **(Figure 4.47b)** is the most advantageous one for earthquakes especially when shear walls of basement floor exist **(Figure 4.47a)**. It is because of the reason that the footing slab with basement walls form a rigid box and avoid the independent movements leading to failure. The continuous footing and the independent footing with tie beams rank next in coping with earthquake forces **(Figure 4.47c)**. The independent footing without tie beams easily suffers earthquake damage (Architectural Institute of Japan, 1970). If the foundations are not tied to each other with tie beams, different movements of foundations cause to destroy the uniformity of the building and tend to damage (Tuna, 2000).

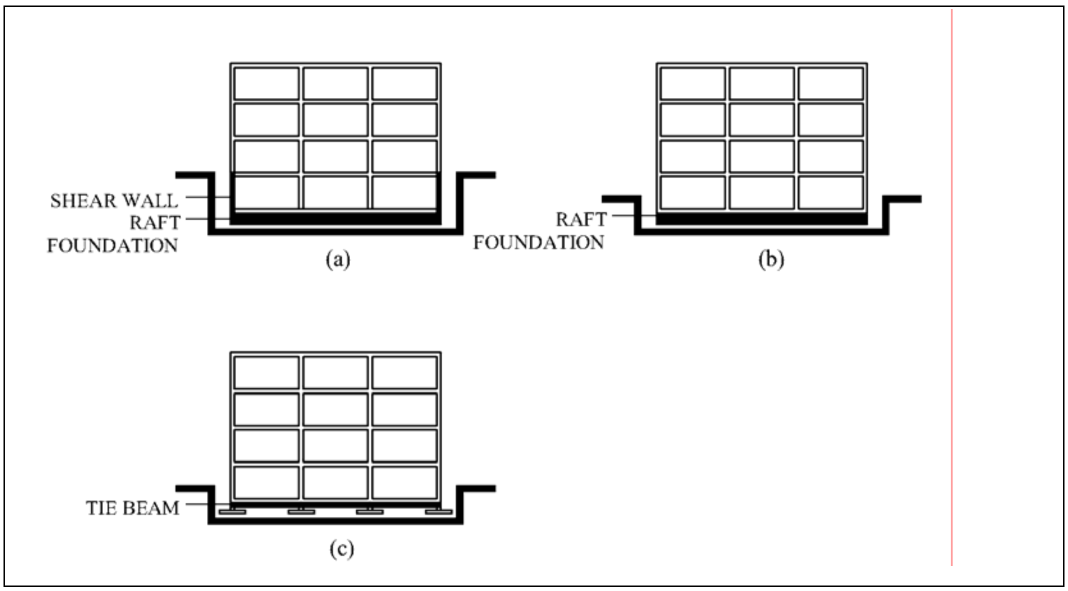

Figure 4.47: Type of foundations for seismic zones

These are the necessities to be avoided during foundation design:

- Unequal settlements of structures due to large variations in subsoil conditions, and foundations resting partly on rock and partly on soil should preferably be avoided (Paulay and Priestley, 1992).
- Using two or more different types of foundation construction in one building should be avoided (Architectural Institute of Japan, 1970).
- Foundation in different heights (for example: graded foundation level on sloppy ground) should be avoided as they transmit earthquake vibrations with time lags. The effects of the vibrations are not uniformly distributed, so the building leads to damage during the earthquake. If it is obligatory, the basement floor should be formed as a rigid box with the surrounding shear walls (Tuna, 2000).
- As an engineering contribution, insufficient foundation depth should be avoided. The type of the soil conditions and the height of the building determine the depth of the foundation (Tuna, 2000).

In the August 17, 1999 Kocaeli Earthquake, apart from structural inadequacy, the widespread foundation displacement, leading to failure as a result of overturning and tilting of the buildings without significant structural distress, is considered as the major factors that caused significant damage to many buildings (Yakut, Gülkan, Bakır and Yılmaz, 2005)

4.3 Architectural Non-structural Components' Configuration Issues

Non-structural components are systems and elements which are housed or attached to the floors, roof and walls of a building and are not part of the main structural system of the building. As they also subject to seismic forces, they must resist these forces depending on their own structural characteristics. In general, the non-structural components may be classified into three categories: architectural components, mechanical and electrical components, building components. Alternative names for 'non-structural components' are 'non-structural elements', 'building attachments', 'architectural, mechanical and electrical elements', 'secondary elements', 'secondary structures', and 'secondary structural elements' (Villaverde, 1997).

Wakabayashi (1986) states that damage of non-structural components have accounted for a significant portion of the total damage cost in earthquakes. Falling ceilings, window glass, exterior claddings, and so on may cause serious injury or death. Collapses of staircases and damage of exit doors may prevent the escape of people from the building. The survival of non-structural components is essential to provide emergency and recovery services after a severe earthquake. Damage to non-structural components may seriously impair a building's function. Experiences from earthquakes have shown that the failure of equipment, overturned and falling objects may critically affect the performance of vital facilities in important buildings such as hospitals, fire and police stations, emergency centers, and so on (Villaverde, 1997). Dowrick (1987) tells an ironic example from the San Fernando earthquake about the inadequacy of a non-structural component. A modern fire station withstood the earthquake satisfactorily with regard to its structure, but the main doors were so badly jammed that all the fire engines were trapped inside.

General Physical Characteristics of Non-structural Components

Many non-structural components are significantly affected by earthquake motions and are susceptible to the effects of earthquakes. According to Villaverde (1997) general physical characteristics of non-structural components are:

- They are usually attached to the elevated portions of a building, and thus they are subjected to the increased motion of the building, not directly to the earthquake motion.
- Their weight is lighter than the structure, to which they are connected, and their stiffness is smaller than the structure as a whole. As a result, some of their natural frequencies are often equal to the natural frequencies of the

structure. Hence, their dynamic response to the motion at their supports may be extraordinarily high.

- They may be connected to the structure at more than one point. Hence, they may be subjected to the distortions due to differential motion of their supports.
- They are often designed to perform a function rather than to resist forces. Therefore, they may be built with materials that are not the ideal materials to resist seismic forces and may be sensitive to even the smallest vibration.

General Response Characteristics of Non-structural Components

The physical characteristics make non-structural components not only susceptible to earthquake damage, but also make their response to earthquake motion unique and different from a building's response. According to Villaverde (1997) some of the response characteristics are:

- The response of a non-structural component depends on the response of its connected structure. Thus, it depends not only on the characteristics of the ground motion but also on the dynamic characteristic of the structure.
- The response of a non-structural component depends on its location within the structure. As a result, identical elements respond differently to earthquake if they are located on different floors of the structure.
- The motion of a non-structural component may modify the motion of its supporting structure. In addition, the motion of its supporting structure may also modify the response of the non-structural component. So, a significant interaction between the non-structural component and its supporting structure may be seen. In such cases, it becomes difficult to predict the response of the non-structural component without knowing the dynamic properties of both the non-structural component and the structure.
- When a non-structural component is connected to the structure at more than one point, the component's supports are subjected by motions, which are different.

- The response of a non-structural component is affected by both its own and its supporting structure' behaviour.

Architectural components are infill walls, partitions, wall finishes, cladding systems, staircases, roofs and part projecting from roofs, suspended ceilings, lighting systems, and so on. In the scope of this thesis, some architectural components are examined.

4.3.1 Partitions and Infill Walls

In the normal practice of structural design, non-structural components are not taken into account. However, completed structures contain various non-structural components such as infill walls and partitions, which influence the behaviour and the safety of the structure. Where the elements are made of very flexible materials, they do not affect the structure significantly, especially when the structural system is stiff. Light partitions such as gypsium and wooden boards or plywood, which are veneered on wooden studs or galvanised U-profiles, do not have significant effects. However, very often they are constructed out of stiff materials such as precast concrete blocks or bricks. In this situation, the influence becomes significant, especially when they are installed in a flexible frame structure (Wakabayashi, 1986; Dowrick, 1987).

Partitions and infill walls have significant rigidities and lateral load carrying capacities, when they are subjected to low lateral loads. Reinforced concrete frame without partitions and infill walls has a longer natural period of vibration than the one with partitions and infill walls. This proves that partitions and infill walls increase the rigidity of the building. The infill walls, installed in a frame, act as shear walls during an earthquake and prevent the excessive displacements of the structure (Bayülke, 2001).

Frame structures without infill walls are more flexible than frame structures with infill walls. The drift of the frame due to lateral loads is greater than the drift of the infill wall in an earthquake. Reinforced concrete frame may make a drift of 1/100 of its height in value, without deformation. However, the infill wall in a frame, having a displacement limit of 1/250 of its height in value, begins to crack even with a few millimeters displacements. When the infill walls exceed their lateral drift limitations, they give up to contribute the structure's rigidity and to bear lateral loads. However, they begin to assist absorbing earthquake energy loading with the friction originating within cracks **(Figure 4.48)** (Bayülke, 2001).

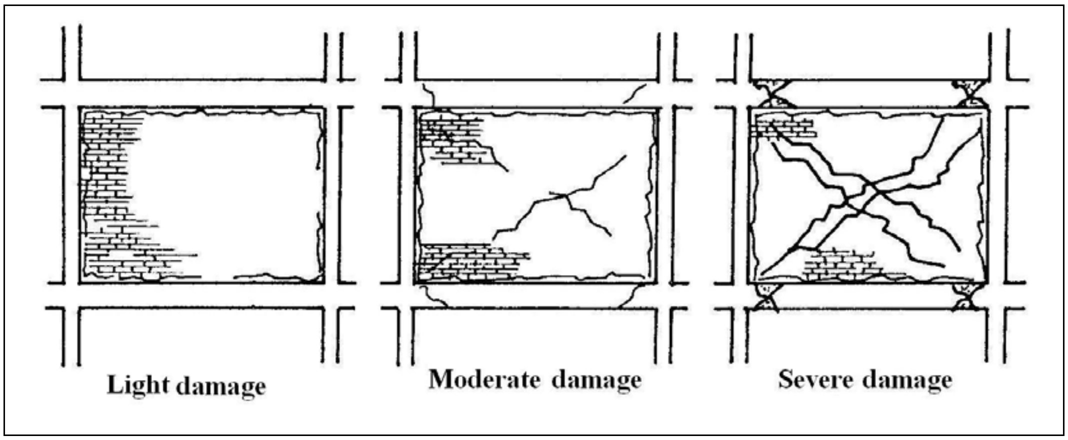

Figure 4.48: Level of damages of infill walls inserted in a frame (Erman, 2002, p.78)

Infill walls restrict the excessive lateral displacements of the frames before they begin to crack and rupture. The damage of the infill walls depends not only the magnitude of the earthquakes, but also the strength of the materials used (Bayülke, 2001). The rigidity of the infill walls made of solid brick is greater than the ones with perforated and brittle brick. Hence, it is appropriate to use earthquake resistant brick instead of using perforated brick, which is brittle and performs poor earthquake resistant. It has been observed that the infill walls with solid bricks are less subjected to damage when they are compared to the perforated ones. Erman (2002) states that, in California, having similar seismic conditions with Turkey, use of perforated brick is forbidden according to their standards and earthquake codes, whereas it has been used in Turkey. The height of the infill is also effective in the formation of damage.

As the height of the wall increases, the overturning risk becomes apparent. Hence, according to the 1998 Turkish Earthquake Code, when the height of an infill wall is more than 3 m, a lintel must be constructed (Tuna, 2000; Bayülke, 2001).

The infill wall, which stands on the floor without framing, is called a free wall. It contributes to earthquake resistance only with its weight. It is probable to overturn and to subject to torsion as it is built out of its plane. In order to prevent infill wall to overturn out of its plane, details should be developed and precautions should be taken **(Figure 4.49)** (Bayülke, 2001).

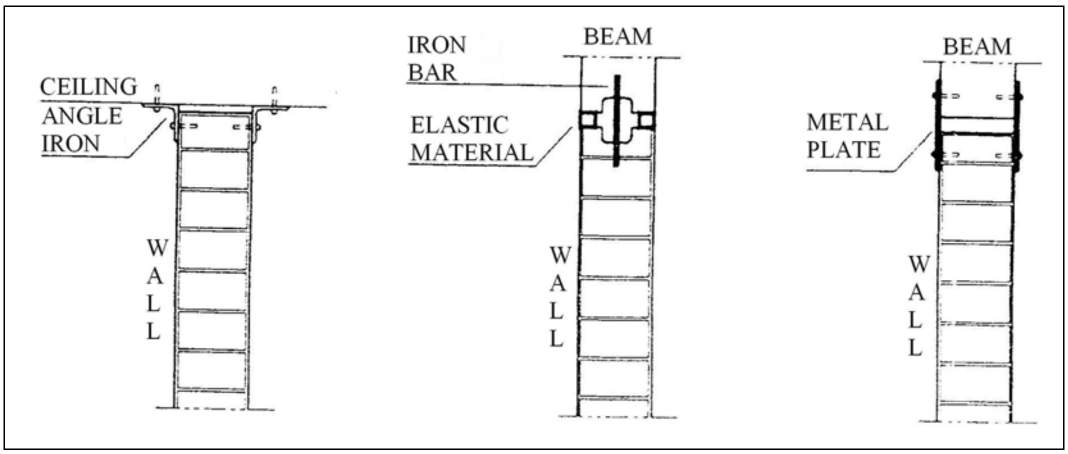

Figure 4.49: Details for an infill wall in order to prevent overturning out of its plane (Bayülke, 2001, p.90)

Two opposite approaches may be adapted for the proper construction of the infill walls **(Figure 4.50)**. These are:

- integrating the infill wall with the structure,
- separating the infill wall from the structure.

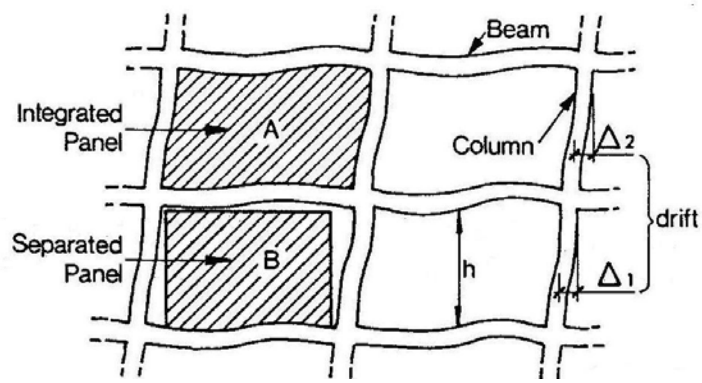

Figure 4.50: Two opposite approaches for frame and non-structural infill wall (Dowrick, 1987, p.444)

Integrating the infill wall with the structure:

The non-structural components are to be taken into account in the design and detailed accordingly. When rigid materials are used, the infill walls should be considered as structural elements. If seismic deformations are to be satisfactorily withstood, reinforcement of integrated rigid walls is usually required. Erman (2002) states that it is appropriate to place reinforcement every 40-60 cm height of the masonry walls made of brick, especially when the frame structure is to be designed with masonry walls. When a non-structural wall is tightly clamped in a structural frame, the wall is forced to deform in a compatible manner with the frame. The wall fails if it is forced by the frame to deform beyond its allowable limit. Therefore, integration of infill and structure is most likely to be successful when very flexible materials are combined with a very stiff structure with many shear walls. This approach makes insulation of water, noise, or heat more feasible than the other approach (Wakabayashi, 1986; Dowrick, 1987).

Separating the infill from the structure

This method is appropriate when a flexible frame is used, exclusively in tall buildings. The infill wall may be uncoupled from the frame. It is fastened to the frame at four corners by an attachment, which allows the wall to slide freely in the wall plane but strongly resists out-of-plane deformation and overturning **(Figure 4.51b)**.

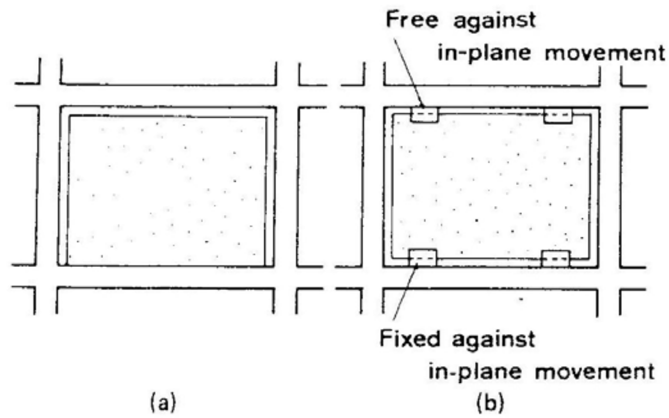

Figure 4.51: Separating the infill wall from the structure (Wakabayashi, 1986, p.269)

The clearance distance between the infill and the structure needs to be determined by considering possible drift of the frame. Bayülke (2001) states that there should be a clearance of h/50-h/100, where h is the free height of the column. This type of construction has two inherent detailing problems. Firstly, awkward details may be required to ensure lateral stability of the elements against forces. Secondly, satisfying water, sound, fire proofing of the separation gap is difficult. If the clearance has to be filled, flexible and elastic material must be used in order to absorb energy loading. The clearance should be padded by filters in order to satisfy water insulation, acoustic and fire resistance requirements. Great care has to be taken during both detailing and building to prevent the gaps being accidentally filled with mortar or plaster (**Figure 4.52)** (Wakabayashi, 1986; Dowrick, 1987)

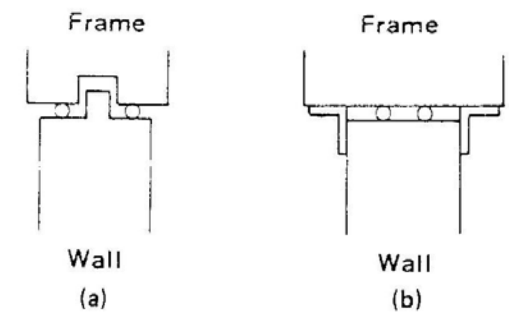

Figure 4.52: Details for isolation (Wakabayashi, 1986, p.269)

According to Dowrick (1987), neither of the solutions is very satisfactory, as the fixings of the necessary ties, reinforcement, dowels, or gap treatments are time-consuming, expensive, and hard to supervise properly. The client should be warned not to permit construction of solid infill walls without taking structural advice about the earthquake effects. Moreover, there is little literature available giving specific guidance on architectural detailing for better seismic performance. Only few countries have codes of practice on this subject.

The problems involved in providing earthquake resistant details for the other non-structural components are the same in principle as those with the partitions and infill walls. The techniques of integral or separated construction must be applied.

4.3.2 Wall Finishes and Claddings

Architectural Institute of Japan (1970) states that selection for the wall and its finishes must be realized taking into considerations whether the main structure is flexible or rigid. For rigid structures, finishes such as stone facing can be utilized, if precautions are taken in the method of attachment. In flexible structures, wall finishes, which can adapt themselves to deflections of the main structure, can be used.

Mortar is used to attach the wall claddings such as stone facing to the walls. However, the adherence, breaking and tensile strength of the mortar are restrictive. The consecutive drift movement due to earthquake forces between stories makes the mortar exceed its strength and makes the finishes separate from the walls due to properties of mortar in between (Bayülke, 2001). Hence, chemical connections, such as mortar, are inconvenient, which are also prohibited in western countries prone to earthquakes. Instead of chemical connections, mechanical connections such as cramp anchorage with proper details and intervals are appropriate to be used (Erman, 2002).

Sandwich walls, which are designed for heat insulation, are also to be tied to each other with cramps in order to prevent overturning due to seismic forces **(Figure 4.53)** (Erman, 2002).

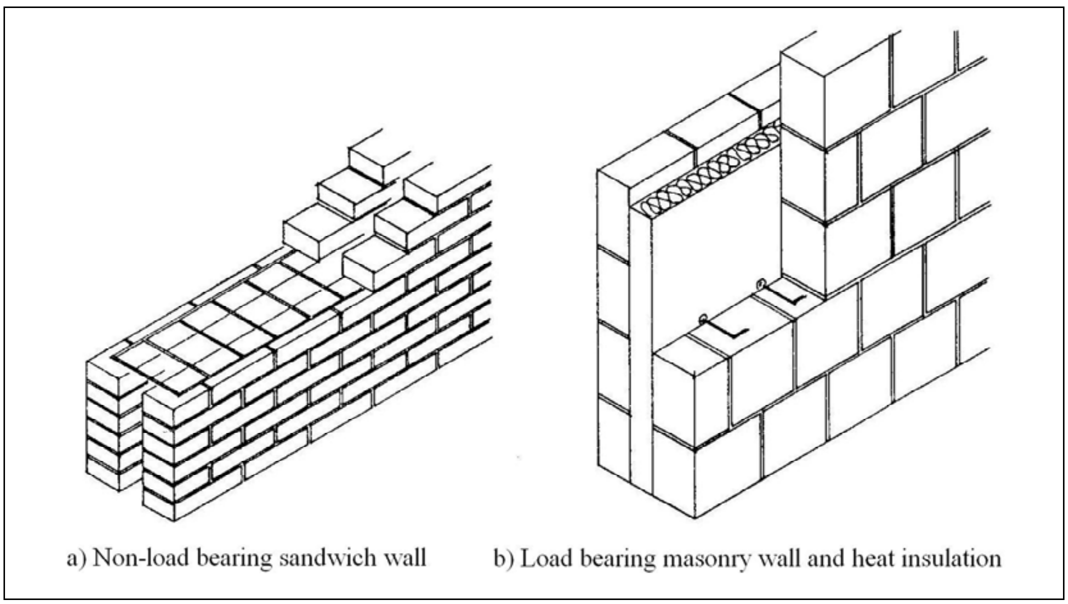

Figure 4.53: Details for sandwich wall (Erman, 2002, p.83)

In flexible structures, it is desirable to avoid the application of brittle and rigid finishes such as stone facing, because walls with rigid parts are first ruptured.

Alternatively, they should be specially detailed on any walls subjected to deformations or drifts. Not only stones, but also large size tiles, terra cotta or precast concrete cladding must be sufficiently tied to the wall by means of metal anchors or specially designed fixings, which are fully separated from the horizontal drift movement of the structure (Architectural Institute of Japan, 1970; Dowrick, 1987). On the other hand, external curtain walls may well be best dealt with as fully framed prefabricated storey-height units mounted on specially designed fixings capable of dealing with seismic movements (Dowrick, 1987)

Brittle materials such as tiles, glass, or stone should not be applied directly to the inside of stairwells, escalators, or open wells. If they must be used, they should be mounted on separate stud walls or furrings. Preferably, stairwells should be free of materials, which may fall off and thus block the exit way or cause injury to persons using the area. Moreover, the parts projecting from the wall must be properly protected. The fall of the projecting parts has the danger of injuries on persons.

4.3.3 Staircases

The role of staircases in an earthquake is critical and vital. Staircases provide escape from the structure. Tuna (2000) states that as the staircases behave as diagonal beams to the lateral forces, axes of them are the most rigid ones in the system when compared to the others. As the distribution of earthquake forces is proportional to the rigidity of the building components, the greatest lateral forces are concentrated on the axes of staircases. Rapidly and safely escape from the structure is provided, if the staircase is able to withstand to the earthquake forces. One of the solutions is to design fixed bearing from one corner of the staircase to the frame and unrestrained bearings from the other corners. Another solution is to separate the staircase as a separate building block with seismic joints. Because of the important responsibility of the staircases in earthquakes, the staircase should remain in use without damage even the main building damages **(Figure 4.54)** (Tuna, 2000; Bayülke, 2001).

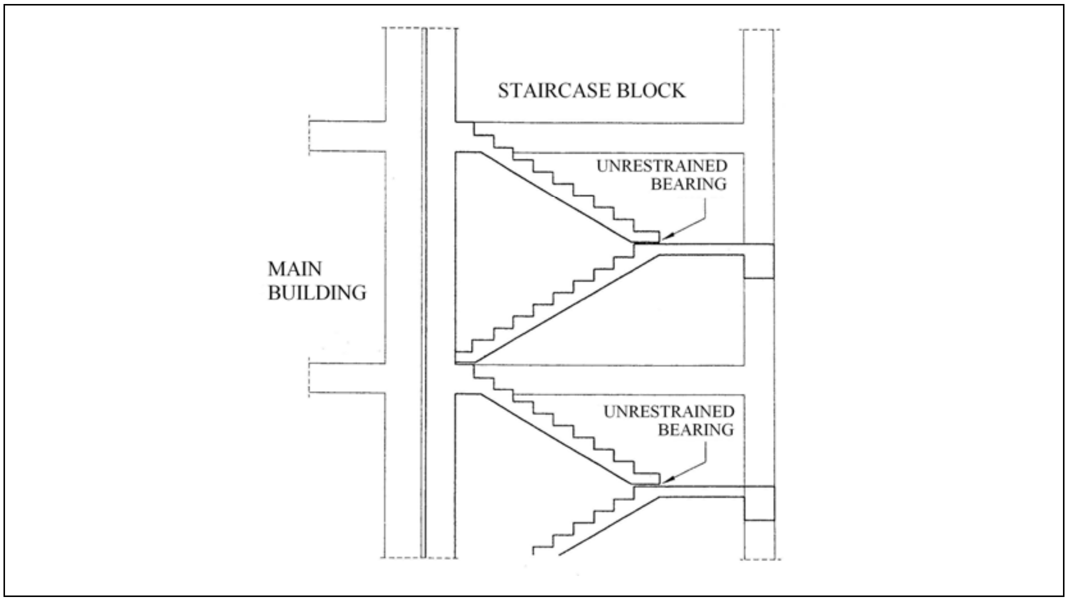

Figure 4.54: Details in order to prevent damage of staircases (Bayülke, 2001, p.96)

The landing of staircases causes short column formation. Moreover, as staircases are subjected too much lateral forces, the infill walls, and corridors of them are destroyed and escape from the staircases becomes difficult. Hence, the staircases and the corridors of them should be surrounded by shear walls in order to form cores (Erman, 2002).

4.3.4 Roofs and Part Projecting from Roof

Roofs

From the viewpoint of seismic performance, light roofs such as sheet metal roofs are desirable. Even if they collapse, percentage of survival of the people staying inside would be high because of the lightness of roof and roof framing members. On the other hand, clay tiles or cement tiles are one of the most undesirable roofing materials from the seismic viewpoint, because they are heavy in weight. Besides the selection of appropriate roofing materials in terms of seismic resistance, attention must be paid to fastening method to the sheathing board. It is recommended that materials such as copper or stainless steel, for which rusting is not expected, are to be used for the fastening metals. Clay tiles or cement tiles being one of the heavy and undesirable roofing materials from the seismic viewpoint are usually fastened without hooking strips to thin sheathing boards by one or two nails per unit. Thus, they may cause collapses of buildings and loss of human lives due to rupturing of roofs (Architectural Institute of Japan, 1970).

Parts Projecting from the Roofs

The installations on the roof such as water tanks or cooling towers, which have the probability to overturn and to fall down, should be anchored properly.

Erman (2002) states that gable walls and the parapets of balconies and terraces, which tend to overturn in an earthquake, should not be built out of masonry construction. They are to be out of reinforced concrete in order not to be separated from the structure. The gable roof is probable to collapse, if the pitched roof is designed parallel to the earthquake force. According to Bayülke (2001), the damage of gable wall may be prevented by placing it between the frames.

4.3.5 Windows and Doors

According to Dowrick (1987), it has been observed that glass breakage costs more than any other single item in earthquakes. If an expected maximum frame deformation is considered to be small, the glass can be fixed by soft putty. If it is large, window sashes should be separated from the frame and clearance must be provided between the window sash and surrounding walls and frames (Wakabayashi, 1986). On the other hand, Dowrick (1987) states that the hard putty glazed windows tend to fail with explosive buckling. Hence, they should be used only where sashes are fully separated from the structure, for example, when glass is in a panel or frame, which is mounted on rockers or rollers.

The glasses of the windows may burst suddenly, if they do not resist the consecutive drifts of the stories. Breakage of window glass is very dangerous, because falling pieces can injure people below. According to Bayülke (2001), when a film with 50 micron in thickness is placed on the glass, dispersion of glass is prevented even it is broken. If the glass of the windows is mounted in a way that permits movement of glass due to lateral displacements, the breakage of the window is prevented. As clearance is provided between glass and sash, glass can ordinarily adapt itselves to deflections of the building **(Figure 4.55a)**. Bayülke (2001) states that windows with metal sashes are to be detailed properly as they are so rigid when compared to the others.

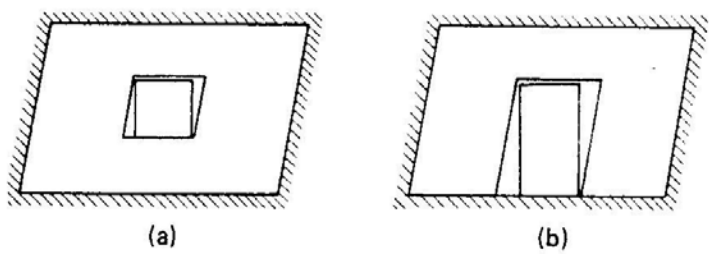

Figure 4.55: Clearance between window (a) or door (b) and walls (Wakabayashi, 1987, p.270)

Doors, which are vital means of entrances, particularly main doors of highly populated and emergency service buildings, should be specially designed to remain functional after a strong earthquake. When walls surrounding a doorway are subjected to large deformation, the door may become jammed. Hence, proper clearance must be provided in order to avoid the situation **(Figure 4.55b)** (Wakabayashi, 1986).

4.3.6 Suspended Ceilings

Suspended ceiling failure may cause critical damage. Since suspended ceiling often falls during earthquake, connections with the suspended members must be properly designed. As the suspended ceiling is subjected to horizontal movement due to seismic forces, a gap should be made at the perimeter of it in order to prevent the ceiling pounding to the walls. One side of the corner is fixed to the structure, where the other is let to slide by movement **(Figure 4.56)** (Dowrick, 1987).

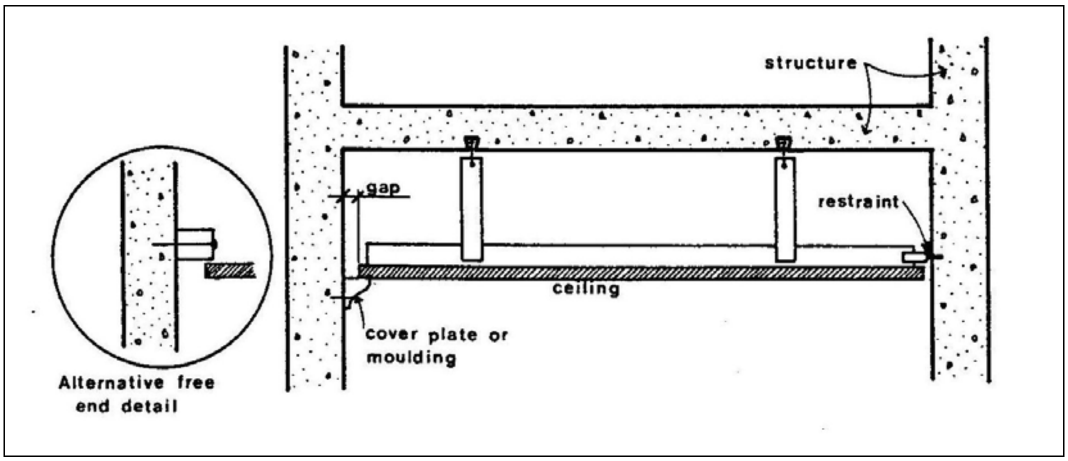

Figure 4.56: Details of suspended ceiling to prevent hammering and excessive movement (Dowrick, 1987, p.451)

Some ceiling suspension systems need additional horizontal restraints at columns and other structural members in order to minimize ceiling motion in relation to the structural frame **(Figure 4.57)**. This reduces hammering damage to the ceilings. Moreover, the ceiling grid members, tiles, become less likely to fall off. The suspension system for the ceiling should also minimize vertical motion in relation to the structure (Dowrick, 1987).

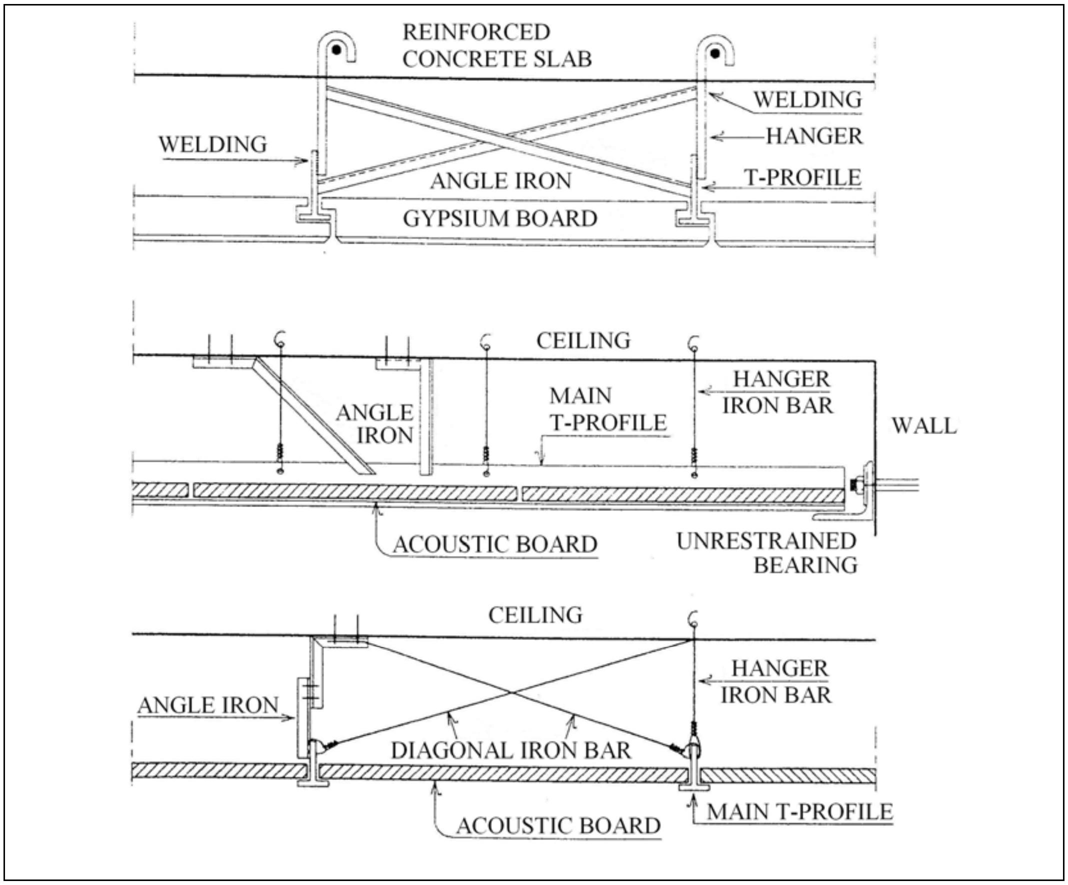

Figure 4.57: Details of suspended ceiling construction (Bayülke, 2001, p.100)

Lighting fixtures, which are dependent upon the ceiling system for support, should be securely tied to the ceiling grid members in order not to fall on the floor. According to Dowrick (1987), if support is likely to be inadequate in earthquakes, the lighting fixtures should be hung independently from the building structure above.

CHAPTER 5

CONCLUSION

5.1 Conclusions

As Turkey is a country prone to earthquakes, ‘earthquake’ is the reality of the geographic structure of the country. When earthquakes strike built environment, in order not to face destructive consequences of earthquakes, buildings must resist earthquake forces and standstill. Accordingly, professionals involved in construction process have their own roles and responsibilities in seismic design. This thesis concentrates on the roles and responsibilities of architects, as being the designer of the buildings and the coordinator of the construction process.

In this research, firstly, with the help of a case study (survey in the form of questionnaires) discussed in Chapter 3, the present state of attitudes (interest, awareness and consciousness) of architectural community towards earthquake and architecture-based issues related to seismic design is searched. Two important issues are tested by the designed hypotheses. First issue of the case study is to explore how architects experience and perceive seismic design. The level of interest and awareness of architects about the significance of architectural designs on seismic performance of buildings and the level of the general knowledge of architects related to architecture-based seismic design issues are examined. By the way, the architectural consciousness in seismic design is evaluated. As the second issue of the case study, the possible ways to enhance the incorporation of ‘earthquake’ as a design parameter with the other and more ordinary ones are investigated.

In this research, then, as being one of the ways, which is mentioned in Chapter 3, for incorporating ‘earthquake’ as a design parameter, architecture-based issues related to seismic design are investigated and explored for the use of architects in Chapter 4. The documentation is presented in an explicit and a compact format, not comprising engineering subjects such as mathematical calculations or static analyses. In order to provide general interest or basic knowledge, documentation such as a handbook or guidance, which is not too complicated and technical, is formed for architects.

There are personal efforts in order to gather the seismic design issues for the use of professionals. The authors of the related books are generally from the profession of engineering, such as structural engineers (Ersoy, Bayülke, Gönençen and Tezcan). Although there are books, written by architects who are interested in seismic design such as Tuna and Erman, and thesis, studied by the graduate students of department of architecture, these studies do not exceed beyond personal researches and efforts. The results of the case study in this thesis, as mentioned in Chapter 3, Section 3.4, and Section 3.5, illustrate the reality that most of the architects have never examined the 1998 Turkish Earthquake Code and the architects, who have examined it, generally are not satisfied with the code from architectural viewpoint. Hence, some specifications as a formal earthquake code for the use of architects should be provided urgently, as nobody knows when and where an earthquake strikes.

The other important result of the case study of the thesis (Chapter 3, Section 3.4 and Section 3.5) is about the necessity of seismic design within architectural education. It is concluded from the case study that seismic design issues should be included and integrated into architecture curricula of departments of architecture. Architecture-based issues in seismic design should be taught in details during architectural education: both in structure and design courses (Chapter 5, Section 5.2). Moreover, obligatory lectures related to earthquake resistant design of buildings may be established by the Chamber of Architects (T.M.M.O.B) for the use of architects, who intend to design buildings and structures on earthquake risky zones. Before designing for these earthquake zones, the chambers may make all these architects participate in the obligatory lectures.

The general principle of earthquake resistant design is to prevent structural and non-structural elements of buildings from any damage in low intensity earthquakes; to limit the damage in structural and non-structural elements to repairable levels in medium-intensity earthquakes, and to prevent the overall or partial collapse of buildings in high-intensity earthquakes in order to avoid the loss of life (Turkish Earthquake Code, 1998).

The mentioned statement should be known by architects and other professions involved in construction process before participating in construction work. The duty of an architect in earthquake resistant building design is to orient people and other professions in the construction process properly. Architects should have knowledge on how to obtain regular architectural design. Accordingly, regular architectural configuration is to be designed; firstly, with its building configuration as a whole; then, with its structural system configuration in plan and in vertical; and finally, with its non-structural architectural components' configuration and their proper architectural detailing.

With proper arrangement and configuration of these architecture-based issues, revisions or probable additional operations on the original architectural plan (such as removal of columns or infill walls, construction of additional voids or staircases, and so on), which are likely to be performed by the users or other professionals due to personal needs, should be prevented. Comments on functional arrangement (configurations of spaces, structural or non-structural elements) should not be left to the non-professionals. Every operation in the building design should be performed and controlled by the designer, the architect, according to the needs of earthquake safety. With relation to this issue, education is also an important consideration for the rest. Everyone including the users of the buildings should be aware that every single operation might change the dynamic behaviour of the building against earthquake forces. Therefore, architectural design should be kept in its original state.

5.2 Recommendations

In terms of the importance of seismic design issues in architectural education, further studies may search for the task of ‘earthquake architecture’ as being one of the ways of introducing seismic design issues into architectural design courses.

Earthquake architecture is an approach to architectural design that draws upon earthquake engineering design issues as a significant source of inspiration (Charleson, Taylor and Preston, 2001). Arnold (1996) describes ‘earthquake architecture’ as the architectural expression of some aspect of earthquake action or resistance in order to contribute architectural enrichment of buildings. These expressive possibilities range from metaphorical and symbolic uses of seismic issues to the exposure of seismic technology (Charleson, Taylor and Preston, 2001). Charleson (2003) states that earthquake architecture helps bridging the gap between structure courses and architectural design studios and facilitates the integration of the two disciplines. By the way, the seismic design issues may be incorporated to the design and the structure courses.

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APPENDIX A
VARIABLE LIST

Table A.1: Variable List

Question No.	Variable No.	Description
1	00001	Graduation school
2	00002	Existence of post graduation
3	00003	Experience in designing building on seismic zone
4	00004	Working experience in architectural office
5	00005a	(Importance level) customer demands as a design criterion
5	00005b	(Importance level) function as a design criterion
5	00005c	(Importance level) aesthetics as a design criterion
5	00005d	(Importance level) environmental factors as design criterion
5	00005e	(Importance level) standards and regularities as a design criterion
5	00005f	(Importance level) architecture-based seismic design issues as a design criterion
5	00005g	(Importance level) other issues as design criteria
6	00006	Effect of architectural design decisions on seismic performance
7	00007a	(Existence level) roles/responsibilities of architects in seismic design
7	00007b	(Existence level) roles/responsibilities of structural engineers in seismic design
7	00007c	(Existence level) roles/responsibilities of contractors in seismic design
7	00007d	(Existence level) roles/responsibilities of controllers in seismic design
7	00007e	(Existence level) roles/responsibilities of others in seismic design
8	00008	Collapses of buildings and losses of lives due to architectural design faults
9	00009	(Existence level) architectural design faults causing collapses of buildings and losses of lives

Table A.1 (continued)

10	00010	(Participation level) architectural design as the starting point of seismic design
11	00011	(Participation level) earthquake as an engineering subject
12	00012	(Participation level) comparison of the roles in seismic design
13	00013	(Participation level) the structural engineers' ability to transform every building into an earthquake resistant one
14	00014	(Participation level) consideration of 'earthquake' as a design criterion
15	00015	(Participation level) 'earthquake' as an obstacle for architectural creativity
16	00016	(Participation level) damages due to architectural design faults
17	00017a	(Importance level) effect of building's form and geometry on seismic performance
17	00017b	(Importance level) effect of building's structural system and its configuration on seismic performance
17	00017c	(Importance level) effect of non-structural architectural components on seismic performance
18	00018	General knowledge in 1998 Earthquake Code
19	00019a	Difficulty to understand 1998 Earthquake Code for architects
19	00019b	Serviceability of 1998 Earthquake Code for architects
19	00019c	Sufficiency of 1998 Earthquake Code for architects
20	00020	Need for an earthquake guidance for architects
21	00021	Mutual coordination with structural engineer
22	00022	Consideration of seismic design as an afterthought
23	00023	Disagreement with structural engineer
24	00024	(Importance level) the negotiation of structural engineer
25	00025	Ways to incorporate earthquake as a design parameter with the other ones

APPENDIX B1

ENGLISH VERSION OF THE QUESTIONNAIRE FORM

DATE:..................

QUESTIONNAIRE NO: ....

EVALUATION OF EARTHQUAKE CONSCIOUSNESS IN ARCHITECTURAL DESIGN

Dear Architect,

As it is obviously known, considerable amount of destructive earthquakes have happened in our country for past years. They have resulted in loss of lives and properties due to the damages and collapses of buildings. Certainly, as being the designers of the buildings, the roles of the architects cannot be denied. This questionnaire is prepared by myself in order to establish the viewpoint of architects, who are working and designing in architectural offices, towards ‘earthquake’ phenomena and to evaluate the general interest, awareness and conscious of them about the architecture-based issues in seismic design.

Please, respond the questions of questionnaire, which is the case study of my MS thesis, properly and sincerely, as I believe to contribute the working field, ‘earthquake resistant building design’, in architectural viewpoint. Thank you for your contribution.

Evgin Mendi

Architect, METU

1. Graduation school? ....……….

		YES	NO
2.	Did you take post graduation education? If the answer is 'YES', state which school and department it was.	1	2
3.	Have you ever designed a building on seismic zone?	YES 1	NO 2

4. What is your working experience in an architectural office?

( ) 1-5 ( ) 6-10 ( ) 11-15 ( ) 16-20 ( ) 21-25 ( ) 26-30 ( ) 31- +

5. What is the importance level of the following design criteria according to your designs?

	VERY IMPORTANT		....		NOT VERY IMPORTANT
Customer demands	1	2	3	4	5
Function	1	2	3	4	5
Aesthetics	1	2	3	4	5
Environmental factors (Climate, orientation, topography, so on)	1	2	3	4	5
Regulations and standards	1	2	3	4	5
Architecture-based seismic design issues	1	2	3	4	5
Other..	1	2	3	4	5

6. What is effect of architectural design decisions on seismic performance of the buildings?

TOO MUCH	1	2	3	4	5	TOO LESS

7. What are the existence level of roles and responsibilities of the following proficiencies in seismic design?

	TOO MUCH		....		TOO LESS
Architects	1	2	3	4	5
Structural engineers	1	2	3	4	5
Contractors	1	2	3	4	5
Controller persons / firms	1	2	3	4	5
Other..	1	2	3	4	5

		YES	NO
8.	İn Turkey, many destructive earthquakes took place during past years resulting in loss of lives and properties due to the damages and collapses of buildings. Do you think architectural design faults are the participant of the results?	1	2

9. (If the answer of the question 8 is 'YES') What is the existence level of the architectural design faults as the participant of the results?

TOO MUCH	1	2	3	4	5	TOO LESS

PLEASE SIGN THE MOST APPROPRIATE CHOICE THAT INDICATE YOUR ATTITUDE

	CERTAINLY AGREE	AGREE	UNDECIDED / NO IDEA	DISAGREE	CERTAINLY DISAGREE
10. Seismic design initiates with the architectural design.	1	2	3	4	5
11. 'Earthquake' is an expertise, which is more related with the engineers.	1	2	3	4	5
12. Structural engineers' responsibility is much more than architects' in seismic design of buildings.	1	2	3	4	5
13. Structural engineers are able to transform every building, no matter how they are designed by architects, into earthquake resistant ones with the static calculations and alternative solutions.	1	2	3	4	5
14. 'Earthquake' must be considered as a design criterion for architects when they are designing on seismic zones.	1	2	3	4	5
15. Architecture-based seismic design issues are obstacles for architectural creativity and freedom.	1	2	3	4	5
16. A significant portion of the damages of buildings due to earthquakes is resulted from architectural design faults formed during architectural design processes.	1	2	3	4	5

17. What is the importance level of the following architecture-based seismic design issues on seismic performance of the buildings, which are designed on seismic zones?

	VERY IMPORTANT	....			NOT VERY IMPORTANT
Form and geometry	1	2	3	4	5
Structural system and its configuration	1	2	3	4	5
Detailing of non-structural architectural components (infill walls, suspended ceilings, doors and windows and so on)	1	2	3	4	5

18. Have you ever examined the irregularities part of 1998 Turkish Earthquake Code, which is more related to architects? YES 1 NO 2

19. (If the answer of the question 18 is 'YES') I think that the subjects of 1998 Turkish Earthquake Code are.................... for architects.

DIFFICULT TO UNDERSTAND	1	2	3	4	5	EASY TO UNDERSTAND
UNSERVICEABLE	1	2	3	4	5	SERVICEABLE
INSUFFICIENT	1	2	3	4	5	SUFFICIENT

	YES	NO
20. Do you think that there should be guidance for architects, which is to be used during architectural design phase?	1	2
21. Do your mutual coordinations with structural engineer during architectural design process include seismic issues?	1	2
22. Do you leave the process of transforming a building into earthquake resistant one to the structural engineers as an afterthought?	1	2
23. Have you experienced disagreement/conflict with structural engineers about the seismic issues during mutual coordinations?	1	2

24. What is the importance level of the negotiation with the structural engineers on the seismic performance of the buildings during architectural design process?

VERY IMPORTANT	1	2	3	4	5	NOT VERY IMPORTANT

25. What should be done in order to incorporate 'earthquake' as a design parameter with the other and more ordinary ones such as customer demand, environmental factors and so on? (You can sign more than one choice.)

( ) Guidance for architects should be prepared.

( ) Architectural-based issues in seismic design should be taught in details during architectural education

( ) The amount of mutual coordination with the structural engineers should be frequent.

( ) Other..………………

26. Please write on the following part if there exist additional subjects you want to state.

APPENDIX B2
TURKISH VERSION OF THE QUESTIONNAIRE FORM

TARİH :....................
ANKET NO:....................

MİMARİ TASARIMDA DEPREM BİLİNCİNİN İNCELENMESİ

Sayın Mimar,

Bilindiği gibi ülkemizde geçmiş yıllarda birçok yıkıcı deprem yaşanmış, yapıların hasar görmesi ve yıkılması sonucunda can ve mal kayıpları meydana gelmiştir. Şüphesiz, yapıların tasarımcıları olarak mimarların deprem konusundaki rolü yadsınamaz. Elinizdeki anket, mimarlık bürolarında çalışan ve tasarım yapan mimarların 'deprem' olgusuna bakış açılarını tespit etmek, 'depreme dayanıklı tasarım' konularına olan genel ilgilerini, haberdar olma durumlarını ve bilinçlerini değerlendirmek amacı ile tarafımdan düzenlenmiştir.

Lütfen, 'depreme dayanıklı tasarım' çalışma alanına mimari açıdan katkıda bulunacağına inandığım tezimin bir parçası olan bu anketi özenle ve samimiyetle cevaplandırınız.
Katkılarınız için teşekkür ederim.

Evgin Mendi
Mimar, ODTÜ

1. Lisans eğitimi aldığınız okul? ....

2. Lisansüstü eğitimi aldınız mı? Cevabınız 'EVET' ise hangi okulda ve hangi bölümde olduğunu belirtiniz.	EVET 1	HAYIR 2
3. Deprem riski olan bölgeler için yapı tasarladınız mı?	EVET 1	HAYIR 2

4. Kaç yıldır mimarlık bürosunda çalışıyorsunuz?

   ( ) 1-5 ( ) 6-10 ( ) 11-15 ( ) 16-20 ( ) 21-25 ( ) 26-30 ( ) 31- ÜSTÜ

5. Tasarımlarınızda aşağıda belirtilen tasarım kriterleri , size göre hangi derecede önemlidir?

	ÇOK ÖNEMLİ	....			HİÇ ÖNEMLİ DEĞİL
Müşteri talepleri	1	2	3	4	5
Fonksiyon	1	2	3	4	5
Estetik	1	2	3	4	5
Çevresel faktörler (İklim, yönlenme, topografya vb.)	1	2	3	4	5
Yönetmelikler ve standartlar	1	2	3	4	5
Deprem ile ilgili mimari konular	1	2	3	4	5
Diğer..	1	2	3	4	5

6. Mimari tasarım kararlarının, yapıların sismik performansına etkisi size göre hangi ölçüdedir?

PEK ÇOK	1	2	3	4	5	ÇOK AZ

7. Aşağıda belirtilen kişilerin depreme dayanıklı yapıların oluşumu için üstlendikleri sorumluluklar ve roller size göre hangi ölçüdedir?

	PEK ÇOK	....			ÇOK AZ
Mimarlar	1	2	3	4	5
İnşaat mühendisleri	1	2	3	4	5
Müteahhit	1	2	3	4	5
Yapı denetimi yapan kişiler / kurumlar	1	2	3	4	5
Diğer...	1	2	3	4	5

8. Ülkemizde geçmiş yıllarda birçok yıkıcı deprem yaşanmış, yapıların hasar görmesi ve yıkılması sonucunda can ve mal kayıpları meydana gelmiştir. Mimari tasarım hatalarının, bu kayıplarda payı olduğunu düşünüyor musunuz?	EVET 1	HAYIR 2

9. (8. sorunun cevabınız 'EVET' ise) Mimari tasarım hatalarının, bu kayıplardaki payı size göre hangi ölçüdedir?

PEK ÇOK	1	2	3	4	5	ÇOK AZ

MEVCUT DURUMUNUZU EN İYİ YANSITAN SEÇENEĞİ İŞARETLEYİNİZ.

	KESİNLİKLE KATILIYORUM	KATILIYORUM	KARARSIZIM / FİKRİM YOK	KATILMIYORUM	KESİNLİKLE KATILMIYORUM
10. Depreme dayanıklı yapı tasarımı mimari tasarım safhasında başlar.	1	2	3	4	5
11. Depremin daha çok mühendisleri ilgilendiren bir uzmanlık alanı olduğunu düşünüyorum.	1	2	3	4	5
12. Depreme dayanıklı yapı tasarımında, inşaat mühendislerinin sorumlulukları mimarlardan daha fazladır.	1	2	3	4	5
13. Bir yapının mimarisi nasıl olursa olsun, inşaat mühendislerin yapacağı statik hesaplamalar ve önereceği çözümler ile yapı, depreme dayanıklı hale getirilebilir.	1	2	3	4	5
14. Deprem riski olan bölgelerde deprem, mimarlar için bir tasarım kriteri olarak düşünülmelidir.	1	2	3	4	5
15. Depreme dayanıklı tasarımda göz önünde bulundurulması gereken konular, mimarların yaratıcılık ve özgürlüklerinin önünde birer engeldir.	1	2	3	4	5
16. Deprem sırasında yapıda meydana gelen hasarların önemli bir bölümü mimari tasarım aşamasında yapılan tasarım hatalarından kaynaklanmaktadır.	1	2	3	4	5

17. Deprem riski olan bölgeler için yapılan mimari tasarımlarda, aşağıda belirtilen konular yapıların sismik performansı, size göre hangi derecede önemlidir?

	ÇOK ÖNEMLİ	....			HİÇ ÖNEMLİ DEĞİL
Yapının formu ve geometrisi	1	2	3	4	5
Taşıyıcı sistem seçimi ve konfigürasyonu	1	2	3	4	5
Yapısal olmayan bileşenlerinin (dolgu duvarlar, asma tavanlar, kapı ve pencereler vb.) detaylandırılması	1	2	3	4	5

18. 1998 Deprem Yönetmeliğinin mimarları ilgilendiren, düzensizlikleri konu alan, kısımlarını incelediniz mi? EVET 1 HAYIR 2

19. (18. sorunun cevabı 'EVET' ise) 1998 Deprem Yönetmeliğinde yer alan konuları mimarlar için .... buluyorum.

ANLAŞILMASI GÜÇ	1	2	3	4	5	ANLAŞILIR
KULLANIŞSIZ	1	2	3	4	5	KULLANIŞLI
YETERSİZ	1	2	3	4	5	YETERLİ

20. Mimari tasarım sürecinde mimarların yararlanacağı mimarlara yönelik bir deprem yönetmeliği olması gerektiğini düşünüyor musunuz?	EVET 1	HAYIR 2
21. Mimari tasarım aşamasında inşaat mühendisleri ile yaptığınız karşılıklı görüşmeler deprem ile ilgili konuları kapsıyor mu?	EVET 1	HAYIR 2
22. Yapıların depreme dayanıklı hale getirilmesini, inşaat mühendisleri ile yapılan görüşmelerde, inşaat mühendisine mi bırakıyorsunuz ?	EVET 1	HAYIR 2
23. İnşaat mühendisleri ile yapılan görüşmelerde, deprem ile ilgili konularda, anlaşmazlık / çatışma yaşıyor musunuz?	EVET 1	HAYIR 2

24. Tasarım aşamasında inşaat mühendisleri ile yapılan görüşmeler, yapıların sismik performansı için, size göre hangi derecede önemlidir?

ÇOK ÖNEMLİ	1	2	3	4	5	HİÇ ÖNEMLİ DEĞİL

25. ‘Deprem’ ile ilgili konuların mimari tasarım ile daha bütünleşik (diğer tasarım kriterleri (müşteri talepleri, çevresel faktörler, vb.) ile aynı seviyede) olması için size göre ne yapılmalıdır? (Birden fazla seçeneği işaretleyebilirsiniz.)

( ) Mimarlara yönelik bir deprem yönetmeliği hazırlanmalı

( ) Mimarlık eğitiminde deprem konuları ayrıntılarıyla ele alınmalı

( ) İnşaat mühendisleri ile yapılan görüşmeler sıklaştırılmalı

( ) Diğer...

26. Ankette yer alan sorulara verdiğiniz yanıtlara ek olarak belirtmek istediğiniz konuları bu bölüme yazabilirsiniz.

APPENDIX C

RESULTS OF STATISTICAL ANALYSIS (SPSS 13.0)

Table C.1: Frequency table of roles and responsibilities of architects in seismic design (Q7, VAR00007a)

(1-too much, 2-much, 3-average, 4-less, 5-too less)

ARCHITECTS' ROLES AND RESPONSIBILITIES

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1,00	36	41,9	42,4	42,4
	2,00	27	31,4	31,8	74,1
	3,00	16	18,6	18,8	92,9
	4,00	4	4,7	4,7	97,6
	5,00	2	2,3	2,4	100,0
	Total	85	98,8	100,0	
Missing	System	1	1,2		
Total		86	100,0		

Table C.2: Frequency table of effect of architectural design decisions on seismic performance (Q6, VAR00006)

(1-too much, 2-much, 3-average, 4-less, 5-too less)

EFFECT OF ARCHITECTURAL DESIGN DECISIONS

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1,00	24	27,9	29,3	29,3
	2,00	28	32,6	34,1	63,4
	3,00	22	25,6	26,8	90,2
	4,00	3	3,5	3,7	93,9
	5,00	5	5,8	6,1	100,0
	Total	82	95,3	100,0	
Missing	System	4	4,7		
Total		86	100,0		

Table C.3: Frequency table of architectural design as the starting point of seismic design (Q10, VAR00010)

(1-strongly agree, 2-agree, 3-undecided/no idea, 4-disagree, 5-strongly disagree)

ARCHITECTURAL DESIGN AS STARTING POINT IN SEISMIC DESIGN

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1,00	39	45,3	45,9	45,9
	2,00	39	45,3	45,9	91,8
	3,00	1	1,2	1,2	92,9
	4,00	5	5,8	5,9	98,8
	5,00	1	1,2	1,2	100,0
	Total	85	98,8	100,0	
Missing	System	1	1,2		
Total		86	100,0		

Table C.4: Chi-square test for architectural-based seismic design issues as design criteria (Q5, VAR00005f) vs. roles and responsibilities of architects in seismic design (Q7, VAR00007a)

(Q5: 1-very important, 2-important, 3-average, 4-not important, 5-not very important; Q7: 1-too much, 2-much, 3-average, 4-less, 5-too less)

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
DESIGN CRITERIA: EARTHQUAKE * ROLES/ RESPONSIBILITIES	84	97,7%	2	2,3%	86	100,0%

EARTHQUAKE AS DESIGN CRITERIA * ROLES AND RESPONSIBILITIES OF ARCHITECTS Crosstabulation

Count

		ROLES AND RESPONSIBILITIES				Total
		1,00	2,00	3,00	4,00	
DESIGN CRITERIA: EARTHQUAKE	1,00	30	16	3	2	51
	2,00	5	7	7	2	21
	3,00	1	4	5	2	12
Total		36	27	15	6	84

Table C.4 (continued)

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	21,326[a]	6	,002
Likelihood Ratio	22,561	6	,001
Linear-by-Linear Association	17,965	1	,000
N of Valid Cases	84		

a. 6 cells (50,0%) have expected count less than 5. The minimum expected count is ,86.

Table C.5: Frequency tables of effect of building's form and geometry, building's structural system and its configuration and non-structural architectural components on seismic performance (with bar charts) (Q17, VAR00017a,b,c)

(1-very important, 2-important, 3-average, 4-not important, 5-not very important)

BUILDING FORM AND GEOMETRY

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1,00	40	46,5	46,5	46,5
	2,00	33	38,4	38,4	84,9
	3,00	11	12,8	12,8	97,7
	4,00	2	2,3	2,3	100,0
	Total	86	100,0	100,0	

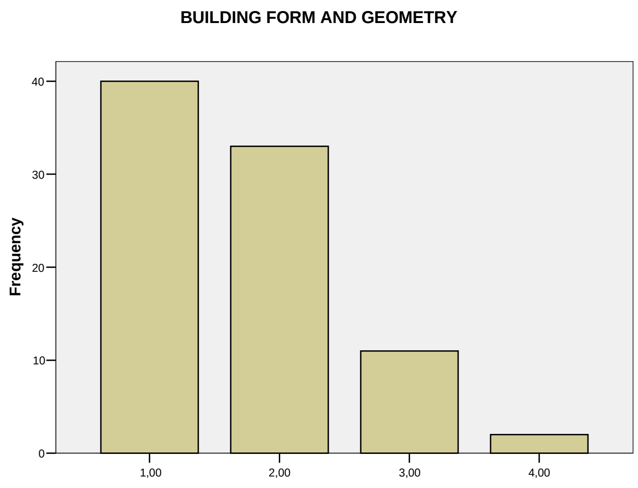
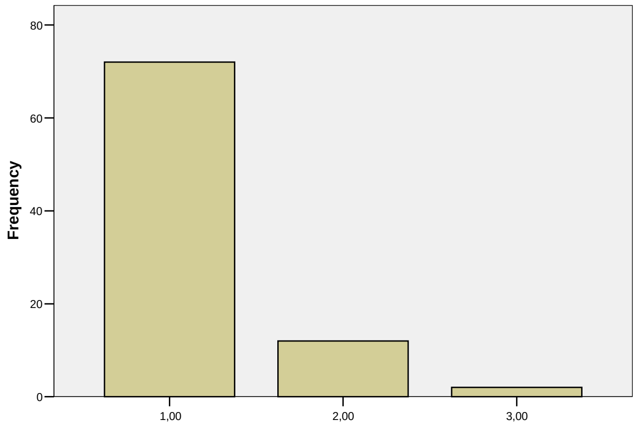


Table C.5 (continued)

STRUCTURAL SYSTEM CONFIGURATION

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1,00	72	83,7	83,7	83,7
	2,00	12	14,0	14,0	97,7
	3,00	2	2,3	2,3	100,0
	Total	86	100,0	100,0	

STRUCTURAL SYSTEM AND ITS CONFIGURATION



ARCHITECTURAL NON-STRUCTURAL COMPONENTS AND DETAILING

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1,00	21	24,4	25,0	25,0
	2,00	21	24,4	25,0	50,0
	3,00	17	19,8	20,2	70,2
	4,00	17	19,8	20,2	90,5
	5,00	8	9,3	9,5	100,0
	Total	84	97,7	100,0	
Missing	System	2	2,3		
Total		86	100,0		

ARCHITECTURAL NON-STRUCTURAL COMPONENTS AND DETAILING

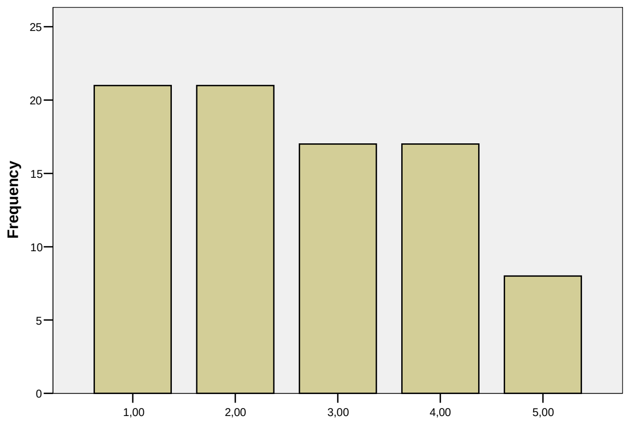


Table C.6: Frequency table of earthquake as an engineering subject (Q11, VAR00011)

(1-strongly agree, 2-agree, 3-undecided/no idea, 4-disagree, 5-strongly disagree)

EARTHQUAKE: ENGINEERING SUBJECT

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1,00	18	20,9	21,7	21,7
	2,00	26	30,2	31,3	53,0
	3,00	2	2,3	2,4	55,4
	4,00	24	27,9	28,9	84,3
	5,00	13	15,1	15,7	100,0
	Total	83	96,5	100,0	
Missing	System	3	3,5		
Total		86	100,0		

Table C.7: Frequency table of comparison of roles and responsibilities of the architects and structural engineers in seismic design (Q12, VAR00012)

(1-strongly agree, 2-agree, 3-undecided/no idea, 4-disagree, 5-strongly disagree)

MORE ROLES/RESPONSIBILITIES FOR STRUCTURAL ENGINEERS

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1,00	31	36,0	36,9	36,9
	2,00	36	41,9	42,9	79,8
	3,00	2	2,3	2,4	82,1
	4,00	13	15,1	15,5	97,6
	5,00	2	2,3	2,4	100,0
	Total	84	97,7	100,0	
Missing	System	2	2,3		
Total		86	100,0		

Table C.8: Frequency table of roles and responsibilities of structural engineers in seismic design (with bar chart) (Q7, VAR00007b)

(1-too much, 2-much, 3-average, 4-less, 5-too less)

ROLES AND RESPONSIBILITIES OF STRUCTURAL ENGINEERS

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1,00	74	86,0	89,2	89,2
	2,00	6	7,0	7,2	96,4
	3,00	3	3,5	3,6	100,0
	Total	83	96,5	100,0	
Missing	System	3	3,5		
Total		86	100,0		

ROLES AND RESPONSIBILITIES OF STRUCTURAL ENGINEERS

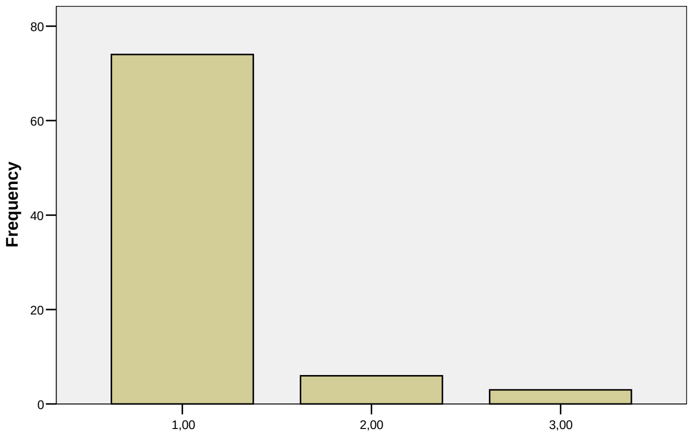


Table C.9: Frequency table of the ability of structural engineers in order to transform every building into an earthquake resistant one (with bar chart) (Q13, VAR00013)

(1-strongly agree, 2-agree, 3-undecided/no idea, 4-disagree, 5-strongly disagree)

STRUCTURAL ENGINEERS' ABILITY

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1,00	15	17,4	17,6	17,6
	2,00	22	25,6	25,9	43,5
	3,00	10	11,6	11,8	55,3
	4,00	24	27,9	28,2	83,5
	5,00	14	16,3	16,5	100,0
	Total	85	98,8	100,0	
Missing	System	1	1,2		
Total		86	100,0		

Table C.10: Frequency table of consideration of seismic design as an afterthought (with bar chart) (Q22, VAR00022)

(1-yes, 2-no)

EARTHQUAKE: AFTERTHOUGHT

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1,00	33	38,4	41,3	41,3
	2,00	47	54,7	58,8	100,0
	Total	80	93,0	100,0	
Missing	System	6	7,0		
Total		86	100,0		

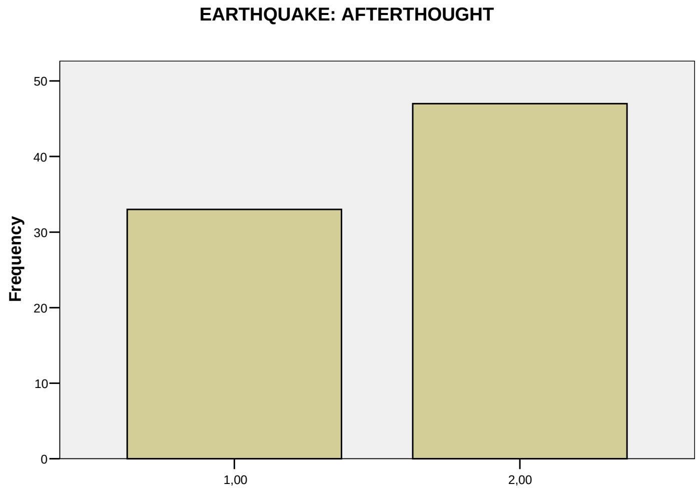


Table C.11: Chi-square test for the structural engineers' ability to transform every building into an earthquake resistant one (Q13, VAR00013) vs. finding earthquake as an engineering subject (Q11, VAR00011)

(1-strongly agree, 2-agree, 3-undecided/no idea, 4-disagree, 5-strongly disagree)

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
STRUCTURAL ENGINEERS' ABILITY * ENGINEERING SUBJECT	83	96,5%	3	3,5%	86	100,0%

RUCTURAL ENGINEERS' ABILITY * EARTHQUAKE: ENGINEERING SUBJE Crosstabulation

Count

		ENGINEERING SUBJECT			Total
		2,00	3,00	4,00	
STRUCTURAL ENGINEERS' ABILITY	2,00	23	0	13	36
	3,00	2	2	5	9
	4,00	19	0	19	38
Total		44	2	37	83

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	19,995[a]	4	,001
Likelihood Ratio	12,857	4	,012
Linear-by-Linear Association	1,426	1	,232
N of Valid Cases	83		

a. 5 cells (55,6%) have expected count less than 5. The minimum expected count is ,22.

Table C.12: Chi-square test for consideration of seismic design as an afterthought (Q22, VAR00022) vs. finding earthquake as an engineering subject (Q11, VAR00011)

(1-strongly agree, 2-agree, 3-undecided/no idea, 4-disagree, 5-strongly disagree)

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
EARTHQUAKE: AFTERTHOUGHT * EARTHQUAKE: ENGINEERING SUBJECT	77	89,5%	9	10,5%	86	100,0%

EARTHQUAKE: AFTERTHOUGHT * EARTHQUAKE: ENGINEERING SUBJECT Crosstabulation

Count

		ENGINEERING SUBJECT					Total
		1,00	2,00	3,00	4,00	5,00	
AFTERTHOUGHT	1,00	11	13	0	6	1	31
	2,00	4	13	1	17	11	46
Total		15	26	1	23	12	77

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	15,528[a]	4	,004
Likelihood Ratio	17,076	4	,002
Linear-by-Linear Association	14,380	1	,000
N of Valid Cases	77		

a. 3 cells (30,0%) have expected count less than 5. The minimum expected count is ,40.

Table C.13: Chi-square test for existence of post graduation (Q2, VAR00002) vs. finding earthquake as an engineering subject (Q11, VAR00011)
(Q2: 1-yes, 2-no; Q11: 1-strongly agree, 2-agree, 3-undecided/no idea, 4-disagree, 5-strongly disagree)

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
POST GRADUATE * EARTHQUAKE: ENGINEERING SUBJECT	81	94,2%	5	5,8%	86	100,0%

POST GRADUATE * EARTHQUAKE: ENGINEERING SUBJECT Crosstabulation

Count

		EARTHQUAKE: ENGINEERING SUBJECT					Total
		1,00	2,00	3,00	4,00	5,00	
POST GRADUATE	1,00	5	13	1	16	11	46
	2,00	13	11	1	8	2	35
Total		18	24	2	24	13	81

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	11,335[a]	4	,023
Likelihood Ratio	11,929	4	,018
Linear-by-Linear Association	10,079	1	,001
N of Valid Cases	81		

a. 2 cells (20,0%) have expected count less than 5. The minimum expected count is ,86.

Table C.14: Frequency tables of design criteria (Q5, VAR00005a-f)
(1-too much, 2-much, 3-average, 4-less, 5-too less)

CUSTOMER DEMAND

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1,00	29	33,7	34,5	34,5
	2,00	30	34,9	35,7	70,2
	3,00	20	23,3	23,8	94,0
	4,00	3	3,5	3,6	97,6
	5,00	2	2,3	2,4	100,0
	Total	84	97,7	100,0	
Missing	System	2	2,3		
Total		86	100,0		

FUNCTION

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1,00	63	73,3	75,9	75,9
	2,00	17	19,8	20,5	96,4
	3,00	2	2,3	2,4	98,8
	4,00	1	1,2	1,2	100,0
	Total	83	96,5	100,0	
Missing	System	3	3,5		
Total		86	100,0		

AESTHETICS

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1,00	52	60,5	61,9	61,9
	2,00	30	34,9	35,7	97,6
	3,00	2	2,3	2,4	100,0
	Total	84	97,7	100,0	
Missing	System	2	2,3		
Total		86	100,0		

Table C.14 (continued)

ENVIRONMENTAL FACTORS

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1,00	53	61,6	62,4	62,4
	2,00	25	29,1	29,4	91,8
	3,00	6	7,0	7,1	98,8
	4,00	1	1,2	1,2	100,0
	Total	85	98,8	100,0	
Missing	System	1	1,2		
Total		86	100,0		

STANDARDS AND REGULATIONS

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1,00	48	55,8	56,5	56,5
	2,00	18	20,9	21,2	77,6
	3,00	15	17,4	17,6	95,3
	4,00	3	3,5	3,5	98,8
	5,00	1	1,2	1,2	100,0
	Total	85	98,8	100,0	
Missing	System	1	1,2		
Total		86	100,0		

EARTHQUAKE

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1,00	51	59,3	60,7	60,7
	2,00	21	24,4	25,0	85,7
	3,00	10	11,6	11,9	97,6
	5,00	2	2,3	2,4	100,0
	Total	84	97,7	100,0	
Missing	System	2	2,3		
Total		86	100,0		

Table C.15: Frequency table of consideration of 'earthquake' as a design criterion (Q14, VAR00014)

(1-strongly agree, 2-agree, 3-undecided/no idea, 4-disagree, 5-strongly disagree)

EARTHQUAKE: DESIGN CRITERIA

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1,00	51	59,3	60,7	60,7
	2,00	31	36,0	36,9	97,6
	3,00	1	1,2	1,2	98,8
	4,00	1	1,2	1,2	100,0
	Total	84	97,7	100,0	
Missing	System	2	2,3		
Total		86	100,0		

Table C.16: Frequency table of 'earthquake' as an obstacle for architectural creativity (with bar chart) (Q15, VAR00015)

(1-strongly agree, 2-agree, 3-undecided/no idea, 4-disagree, 5-strongly disagree)

EARTHQUAKE: AN OBSTACLE

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1,00	3	3,5	3,6	3,6
	2,00	21	24,4	25,0	28,6
	3,00	8	9,3	9,5	38,1
	4,00	35	40,7	41,7	79,8
	5,00	17	19,8	20,2	100,0
	Total	84	97,7	100,0	
Missing	System	2	2,3		
Total		86	100,0		

EARTHQUAKE: AN OBSTACLE

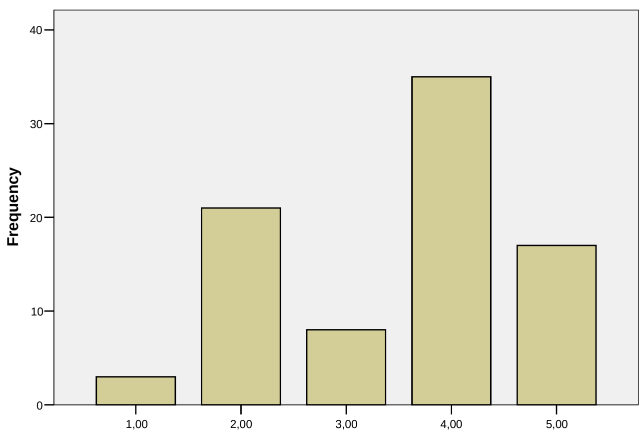


Table C.17: Frequency table of collapses of buildings and losses of lives due to architectural design faults (Q8, VAR00008)
(1-yes, 2-no)

EXISTENCE OF ARCHITECTURAL DESIGN FAULTS

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1,00	63	73,3	74,1	74,1
	2,00	22	25,6	25,9	100,0
	Total	85	98,8	100,0	
Missing	System	1	1,2		
Total		86	100,0		

Table C.18: Frequency table of architectural design faults causing collapses of buildings and losses of lives (with bar chart) (Q9, VAR00009)
(1-too much, 2-much, 3-average, 4-less, 5-too less)

EXISTENCE LEVEL OF ARCHITECTURAL DESIGN FAULTS

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1,00	5	5,8	8,2	8,2
	2,00	14	16,3	23,0	31,1
	3,00	34	39,5	55,7	86,9
	4,00	4	4,7	6,6	93,4
	5,00	4	4,7	6,6	100,0
	Total	61	70,9	100,0	
Missing	System	25	29,1		
Total		86	100,0		

ARCHITECTURAL DESIGN FAULTS

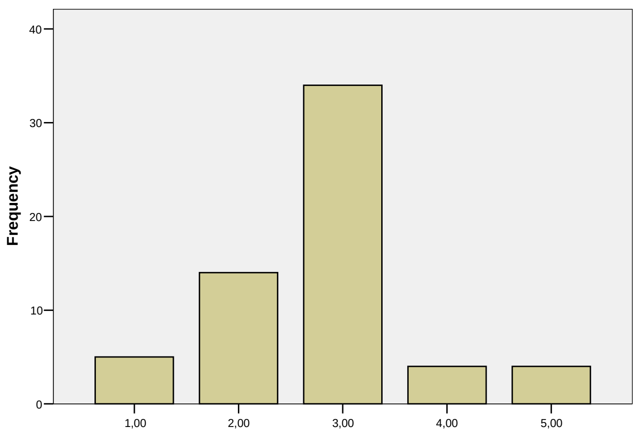


Table C.19: Frequency table of damages due to architectural design faults (Q16, VAR00016)

(1-strongly agree, 2-agree, 3-undecided/no idea, 4-disagree, 5-strongly disagree)

DAMAGES DUE TO ARCHITECTURAL DESIGN FAULTS

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2,00	21	24,4	25,0	25,0
	3,00	10	11,6	11,9	36,9
	4,00	40	46,5	47,6	84,5
	5,00	13	15,1	15,5	100,0
	Total	84	97,7	100,0	
Missing	System	2	2,3		
Total		86	100,0		

Table C.20: Chi-square test for collapses of buildings and losses of lives due to architectural design faults (Q8, VAR00008) vs. consideration of 'earthquake' as a design criterion (Q14, VAR00014)

(Q8: 1-yes, 2-no; Q14: 1-strongly agree, 2-agree, 3-undecided/no idea, 4-disagree, 5-strongly disagree)

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
ARCHITECTURAL FAULTS * DESIGN CRITERIA	83	96,5%	3	3,5%	86	100,0%

ARCHITECTURAL DESIGN FAULTS * EARTHQUAKE: DESIGN CRITERIA Crosstabulation

Count

		DESIGN CRITERIA			Total
		2,00	3,00	4,00	
ARCHITECTURAL FAULTS	1,00	62	0	0	62
	2,00	19	1	1	21
Total		81	1	1	83

Table C.20 (continued)

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	6,051[a]	2	,049
Likelihood Ratio	5,646	2	,059
Linear-by-Linear Association	5,367	1	,021
N of Valid Cases	83		

a. 4 cells (66,7%) have expected count less than 5. The minimum expected count is ,25.

Table C.21: Frequency table of general knowledge in 1998 Turkish Earthquake Code (Q18, VAR00018)

(1-yes, 2-no)

KNOWLEDGE IN 1998 TURKISH EARTHQUAKE CODE

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1,00	23	26,7	27,1	27,1
	2,00	62	72,1	72,9	100,0
	Total	85	98,8	100,0	
Missing	System	1	1,2		
Total		86	100,0		

Table C.22: Frequency table of difficulty to understand 1998 Turkish Earthquake Code for architects (with bar chart) (Q19, VAR00019a)

(2-difficult to understand, 3-average, 4-easy to understand)

DIFFICULTY

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2,00	8	9,3	42,1	42,1
	3,00	6	7,0	31,6	73,7
	4,00	5	5,8	26,3	100,0
	Total	19	22,1	100,0	
Missing	System	67	77,9		
Total		86	100,0		

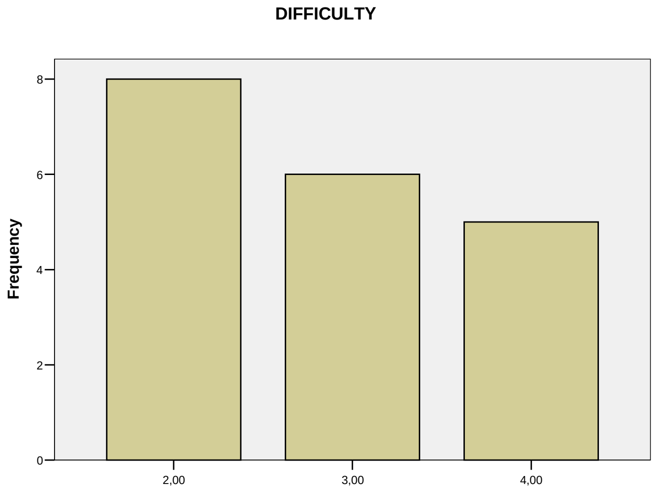


Table C.23: Frequency table of serviceability of 1998 Turkish Earthquake Code for architects (with bar chart) (Q19, VAR00019b)

(2-unserviceable, 3-average, 4-serviceable)

SERVICEABILITY

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2,00	7	8,1	38,9	38,9
	3,00	6	7,0	33,3	72,2
	4,00	5	5,8	27,8	100,0
	Total	18	20,9	100,0	
Missing	System	68	79,1		
Total		86	100,0		

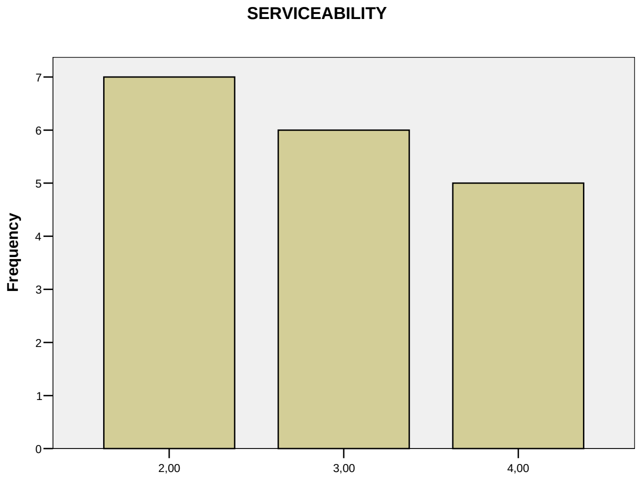


Table C.24: Frequency table of sufficiency of 1998 Turkish Earthquake Code for architects (with bar chart) (Q19, VAR00019c)

(2- insufficient, 3-average, 4-sufficient)

SUFFICIENCY

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2,00	11	12,8	52,4	52,4
	3,00	3	3,5	14,3	66,7
	4,00	7	8,1	33,3	100,0
	Total	21	24,4	100,0	
Missing	System	65	75,6		
Total		86	100,0		

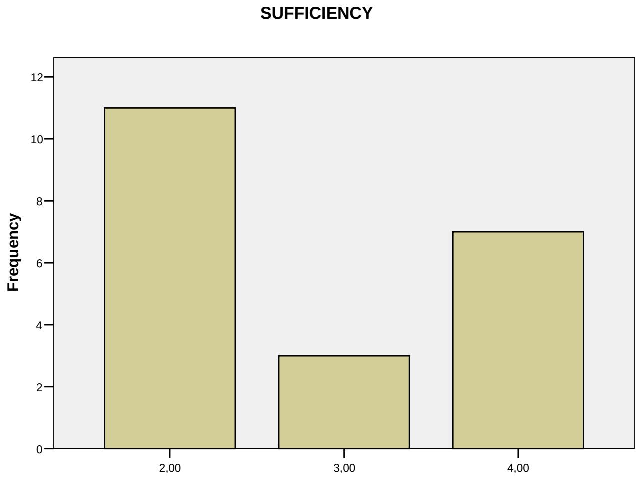


Table C.25: Chi-square test for serviceability of 1998 Turkish Earthquake Code for architects (Q19, VAR00019b) vs. need for earthquake guidance for architects (Q20, VAR00020)

(Q19: 2-not serviceable, 3-average, 4-serviceable; Q20: 1-yes, 2-no)

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
SERVICEABILITY * NEED FOR GUIDANCE	17	19,8%	69	80,2%	86	100,0%

SERVICEABILITY * NEED FOR GUIDANCE Crosstabulation

Count

		NEED FOR GUIDANCE		Total
		1,00	2,00	
SERVICEABILITY	2,00	7	0	7
	3,00	6	0	6
	4,00	2	2	4
Total		15	2	17

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	7,367[a]	2	,025
Likelihood Ratio	6,770	2	,034
Linear-by-Linear Association	4,794	1	,029
N of Valid Cases	17		

a. 4 cells (66,7%) have expected count less than 5. The minimum expected count is ,47.

Table C.26: Chi-square test for experience in designing building on seismic zone (Q3, VAR00003) vs. general knowledge in 1998 Turkish Earthquake Code (Q18, VAR00018)

(1-yes, 2-no)

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
DESIGNING EXPERIENCE* EARTHQUAKE CODE KNOWLEDGE	85	98,8%	1	1,2%	86	100,0%

XPERIENCE IN DESIGNING * EARTHQUAKE CODE KNOWLEDG Crosstabulation

Count

		EARTHQUAKE CODE KNOWLEDGE		Total
		1,00	2,00	
EXPERIENCE IN DESIGNING	1,00	19	32	51
	2,00	4	30	34
Total		23	62	85

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	6,716[b]	1	,010		
Continuity Correction[a]	5,486	1	,019		
Likelihood Ratio	7,273	1	,007		
Fisher's Exact Test				,012	,008
Linear-by-Linear Association	6,637	1	,010		
N of Valid Cases	85				

a. Computed only for a 2x2 table

b. 0 cells (,0%) have expected count less than 5. The minimum expected count is 9,20.

Table C.27: Chi-square test for working experience in architectural office (Q4, VAR00004) vs. general knowledge in 1998 Turkish Earthquake Code (Q18, VAR00018)

(Q4: 1(1-5), 2(6-10), 3(11-15), 4(16-20), 5(21-25), 6(26-30), 7(31-+);

Q18: 1-yes, 2-no)

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
WORKING EXPERIENCE * EARTHQUAKE CODE KNOWLEDGE	76	88,4%	10	11,6%	86	100,0%

XPERIENCE IN WORKING *EARTHQUAKE CODE KNOWLEDG Crosstabulation

Count

		EARTHQUAKE CODE KNOWLEDGE		Total
		1,00	2,00	
EXPERIENCE IN DESIGNING	1,00	1	23	24
	2,00	2	14	16
	3,00	3	9	12
	4,00	2	1	3
	5,00	5	6	11
	6,00	1	1	2
	7,00	6	2	8
Total		20	56	76

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	22,612[a]	6	,001
Likelihood Ratio	22,989	6	,001
Linear-by-Linear Association	20,750	1	,000
N of Valid Cases	76		

a. 8 cells (57,1%) have expected count less than 5. The minimum expected count is ,53.

Table C.28: Chi-square test for experience in designing building on seismic zone (Q3, VAR00003) vs. need for earthquake guidance for architects (Q20, VAR00020) (1-yes, 2-no)

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
DESIGNING EXPERIENCE * NEED FOR GUIDANCE	85	98,8%	1	1,2%	86	100,0%

EXPERIENCE IN DESIGNING * NEED FOR GUIDANCE Crosstabulation

Count

		NEED FOR GUIDANCE		Total
		1,00	2,00	
EXPERIENCE IN DESIGNING	1,00	37	14	51
	2,00	31	3	34
Total		68	17	85

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	4,424[b]	1	,035		
Continuity Correction[a]	3,336	1	,068		
Likelihood Ratio	4,830	1	,028		
Fisher's Exact Test				,052	,031
Linear-by-Linear Association	4,372	1	,037		
N of Valid Cases	85				

a. Computed only for a 2x2 table

b. 0 cells (,0%) have expected count less than 5. The minimum expected count is 6,80.

Table C.29: Chi-square test for working experience in architectural office (Q4, VAR00004) vs. need for earthquake guidance for architects (Q20, VAR00020)
(Q4: 1(1-5), 2(6-10), 3(11-15), 4(16-20), 5(21-25), 6(26-30), 7(31-+);
Q20: 1-yes, 2-no)

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
WORKING EXPERIENCE * NEED FORGUIDANCE	76	88,4%	10	11,6%	86	100,0%

WORKING EXPERIENCE * NEED FOR GUIDANCE Crosstabulation

Count

		NEED FOR GUIDANCE		Total
		1,00	2,00	
EXPERIENCE IN WORKING	1,00	22	2	24
	2,00	7	9	16
	3,00	11	1	12
	4,00	3	0	3
	5,00	12	0	12
	6,00	2	0	2
	7,00	3	4	7
Total		60	16	76

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	25,449[a]	6	,000
Likelihood Ratio	26,084	6	,000
Linear-by-Linear Association	,267	1	,605
N of Valid Cases	76		

a. 8 cells (57,1%) have expected count less than 5. The minimum expected count is ,42.

Table C.30: Frequency table of mutual coordination with structural engineer (Q21, VAR00021)

(1- yes, 2-no)

MUTUAL COORDINATION

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1,00	77	89,5	92,8	92,8
	2,00	6	7,0	7,2	100,0
	Total	83	96,5	100,0	
Missing	System	3	3,5		
Total		86	100,0		

Table C.31: Frequency table of the negotiation of structural engineer (Q24, VAR00024)

(1-very important, 2-important, 3-average, 4-not important, 5-not very important)

IMPORTANCE OF NEGOTIATION

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1,00	55	64,0	64,0	64,0
	2,00	26	30,2	30,2	94,2
	3,00	4	4,7	4,7	98,8
	4,00	1	1,2	1,2	100,0
	Total	86	100,0	100,0	

Table C.32: Chi-square test for mutual coordination with structural engineer (Q21, VAR00021) vs. roles and responsibilities of architects in seismic design (Q7, VAR00007a)

(Q21: 1-yes, 2-no; Q7: 1-too much, 2-much, 3-average, 4-less, 5-too less)

Case Processing

	Cases					
	Valid		Missin		Total	
	N	Percen	N	Percen	N	Percen
COORDINATIO ROLE RESPONSIBILI	82	95,3%	4	4,7%	86	100,0

MUTUAL COORDINATION * ROLES AND RESPONSIBILITIES OF ARCHITECTS Crosstabulation

Count

		ROLES AND RESPONSIBILITIES				Total
		1,00	2,00	3,00	4,00	
COORDINATION	1,00	35	25	13	3	76
	2,00	1	1	2	2	6
Total		36	26	15	5	82

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	10,232[a]	3	,017
Likelihood Ratio	6,803	3	,078
Linear-by-Linear Association	7,060	1	,008
N of Valid Cases	82		

a. 5 cells (62,5%) have expected count less than 5. The minimum expected count is ,37.

Table C.33: Frequency table of consideration of seismic design as an afterthought (Q22, VAR00022)

(1-yes, 2-no)

EARTHQUAKE: STRUCTURAL ENGINEERS' SUPPLEMENT

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1,00	33	38,4	41,3	41,3
	2,00	47	54,7	58,8	100,0
	Total	80	93,0	100,0	
Missing	System	6	7,0		
Total		86	100,0		

Table C.34: Frequency table of disagreement/conflict with structural engineer (Q23, VAR00023)

(1-yes, 2-no)

DISAGREEMENT/CONFLICT WITH STRUCTURAL ENGINEERS

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1,00	38	44,2	46,3	46,3
	2,00	44	51,2	53,7	100,0
	Total	82	95,3	100,0	
Missing	System	4	4,7		
Total		86	100,0		

Table C.35: Frequency table of guidance in order to enhance the incorporation of ‘earthquake’ as a design parameter with the other ones (Q25, VAR00025a)

INCORPORATION: NEED FOR GUIDANCE

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	NO	32	37,2	37,6	37,6
	YES	53	61,6	62,4	100,0
	Total	85	98,8	100,0	
Missing	System	1	1,2		
Total		86	100,0		

Table C.36: Frequency table of architectural education in order to enhance the incorporation of 'earthquake' as a design parameter with the other ones (Q25, VAR00025b)

INCORPORATION: ARCHITECTURAL EDUCATION

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	NO	16	18,6	18,8	18,8
	YES	69	80,2	81,2	100,0
	Total	85	98,8	100,0	
Missing	System	1	1,2		
Total		86	100,0		

Table C.37: Frequency table of mutual coordination in order to enhance the incorporation of 'earthquake' as a design parameter with the other ones (Q25, VAR00025c)

INCORPORATION: MUTUAL COORDINATION

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	NO	30	34,9	35,3	35,3
	YES	55	64,0	64,7	100,0
	Total	85	98,8	100,0	
Missing	System	1	1,2		
Total		86	100,0		