Take Step 1 For a Safe Life!

Istanbul Seismic Risk Mitigation and Emergency Preparedness Project
**ISMEP**

# Structural Risk Mitigation Against Earthquake

ISTANBUL AFAD
PROVINCIAL DISASTER AND EMERGENCY DIRECTORATE

“Disaster Preparedness Training Materials for Community" which are financed in the framework of 4784-TU numbered contract of loan from World Bank and conducted by Istanbul Special Provincial Administration Istanbul Project Coordination Unit (IPCU) within the A component of “Istanbul Seismic Risk Mitigation and Emergency Preparedness Project” (ISMEP) are prepared by Beyaz Gemi Training and Consulting.

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Dear residents of Istanbul,

Istanbul is a city, which is under the threat of earthquakes and many other disaster risks. In many parts of the world, precautions are taken and some preparation plans are carried out against these kinds of risks. In Turkey, there are studies, which aim at the protection of public buildings, particularly schools and hospitals, and historical monuments and there are retrofitting studies for the whole infrastructure system, especially for transportation and communication, with the participation of the professionals in our country by evaluating the studies made in developed countries.

Physical retrofitting studies have the aim of eliminating the physical threats by earthquakes. But the case of earthquake preparedness is not limited with these activities. What's more important is to change our way of life in such a way to be ready for earthquakes and to be more sensitive for our surrounding.

In order to be ready for earthquakes firstly at individual and then at the national level, we should know about earthquakes, we should develop ourselves by having safe life awareness at our home, in our offices and surrounding, we should get training and above all we should become conscious about what we can do before a possible earthquake strike.

Therefore, we have prepared these awareness raising and training materials to reach you by the means of ISMEP (Istanbul Seismic Risk Mitigation and Emergency Preparedness Project), which is conducted by Istanbul Governorship Provincial Disaster and Emergency Directorate and Istanbul Governorship Special Provincial Administration Istanbul Project Coordination Unit. The documents, which are prepared with the help of specialists from civil and private sectors, are given the last shape after the controls of experts and relevant departments.

Fifteen different training titles have been defined for our editions, which require the preparation of different documents with different themes and appropriate contents for them have been developed to reach all our citizens living in Istanbul and to ensure the institutional preparedness in every sense. We wholeheartedly believe that these training materials which are thought to be appreciated by each institution and individual would meet an important need. Before anything else, to know that our dear citizens would benefit from these activities that would help earthquake preparedness, gratifies us and enlivens our studies.

In Istanbul, where the future is strengthened by us, we share happiness of looking to the future with confidence.

Best regards,
Muammer Güler
Governor of Istanbul

**Within the context of Enhancing Emergency Preparedness Capacity,** which is the A component of Istanbul Seismic Risk Mitigation and Emergency Preparedness Project, multiple cooperation has a significant role in Community Disaster Preparedness Training Materialsí shaping within the framework of best practice and achieving objectives.

Within the framework of this project, which is a product of long and intensive study, and emerged in the light of profound knowledge and experiences of a good deal of people and institutions, we thank all public corporations and institutions who do not withhold their contributions from us;

**Republic of Turkey Prime Ministry 'The Presidency of Disaster and Emergency Management Agency'**
**Republic of Turkey Prime Ministry Undersecretariat of Treasury and Foreign Trade**
**Republic of Turkey Prime Ministry State Planning Organization**
**Republic of Turkey Prime Ministry Housing Development Administration**
**Republic of Turkey Prime Ministry Social Services and Child Protection Agency General Directorate**
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**Union of Chambers of Turkish Engineers and Architects**
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**Union of Municipalities and Straits of The Marmara Region**
**The Turkish Contractors Association**
**Union of Building Inspector Companies**
**Istanbul Chamber of Commerce**
**Istanbul Chamber of Industry**
**Turkish Red Crescent Society Training Department**
**Neighbourhood Disaster Volunteers Foundation**
**Istanbul Anatolian Side Neighbourhood Disaster Volunteers Association**
**Search and Rescue Association (AKUT)**
**Istanbul Union of Chamber of Merchants and Craftsmen**
**Radio Amateurs Association**
**Confederation of Turkish Chamber of Merchants and Craftsmen Union**
**Confederation of Turkish Labor Unions**
**Social Service Employees Association**
**Turkish Psychological Association**
**The Psychiatric Association of Turkey**
**Turkish Federation for the Physically Disabled**
**Japan International Cooperation Agency Istanbul Office (JICA)**

And we thank non-governmental organizations, all publication owners in the bibliography, and project team for their meticulous and devoted efforts.

**Republic of Turkey Governorship of Istanbul**
**Provincial Disaster and Emergency Directorate**

# CONTENT

# INTRODUCTION

In this document, behavior of the buildings used as education, health services etc. under strong ground motion are investigated. To achieve this purpose, information about the earthquake performance of the buildings and deficient of the buildings according to desired performance levels are given and structural awareness of the public is aimed.

How the structural elements of the buildings resist to seismic forces, engineering design of the structures, starting from the building to using steps, the problems that can affect the earthquake performance during life time of the building is focused.

In this booklet, basic philosophy of the earthquake resistant design and building is included. The main purpose is; to inform public about the earthquake resistant design, to evaluate the existing buildings according to this philosophy, to provide public demand for the best quality building stock. It is to be noted that the given information must be taken as advices. Only civil engineers who have sufficient professional experience and academic knowledge about the earthquake resistant design are capable of evaluating the structures.

In the booklet, technical subjects are simply explained. In other words, the importance of the subject being understood by users of the buildings is aimed. According to this knowledge, they will determine the applications that have to be avoided or should be applied.

In this manner, knowledge of all the steps of the earthquake resistant design such as design, use and lifetime of the structures, will make public to question all phase of building and workers to have secure buildings.

Public support is expected for the risks that caused from the existing building stock in the cities by the advices written below. This will help cities to grow in safe. Explaining the results of existing risks which may cause great economic loss and social impacts will help government to have decisions more efficiently.

# TECHTONIC STRUCTURE OF THE EARTH

Especially after 1999 Kocaeli earthquake people became more aware of earthquake and started to heave some information on how earthquake happens, how does it affect buildings and many other earthquake related issues. In order to avoid misunderstanding and giving wrong information about earthquakes it is very important to give basic knowledge.

200 million years before, Earth was formed with one continent called "pangea" and with oceans. 180 million years before, the inner core exposed heat that causes this plate to change its form by cracks. After cracks, parts had some movements such as diverging, rising up and falling down. These movements are expressed by "techtonic plate theory".

There are some cracks occurred during motion of the plates called faults. Energy is accumulated in faults. When the energy level reaches to certain level, energy is released which causes shaking in plates. This shaking after caused by energy release is called earthquake.

Energy release can be explained by a simple example. For instance, take a slim wood stick. Trying to break stick gives some crack sound after resisting up to certain level. The position of the cracks depicts the faults and energy release depicts the earthquakes. Because techtonic plates keep going its movements, earthquakes are natural events that can occur in every time.

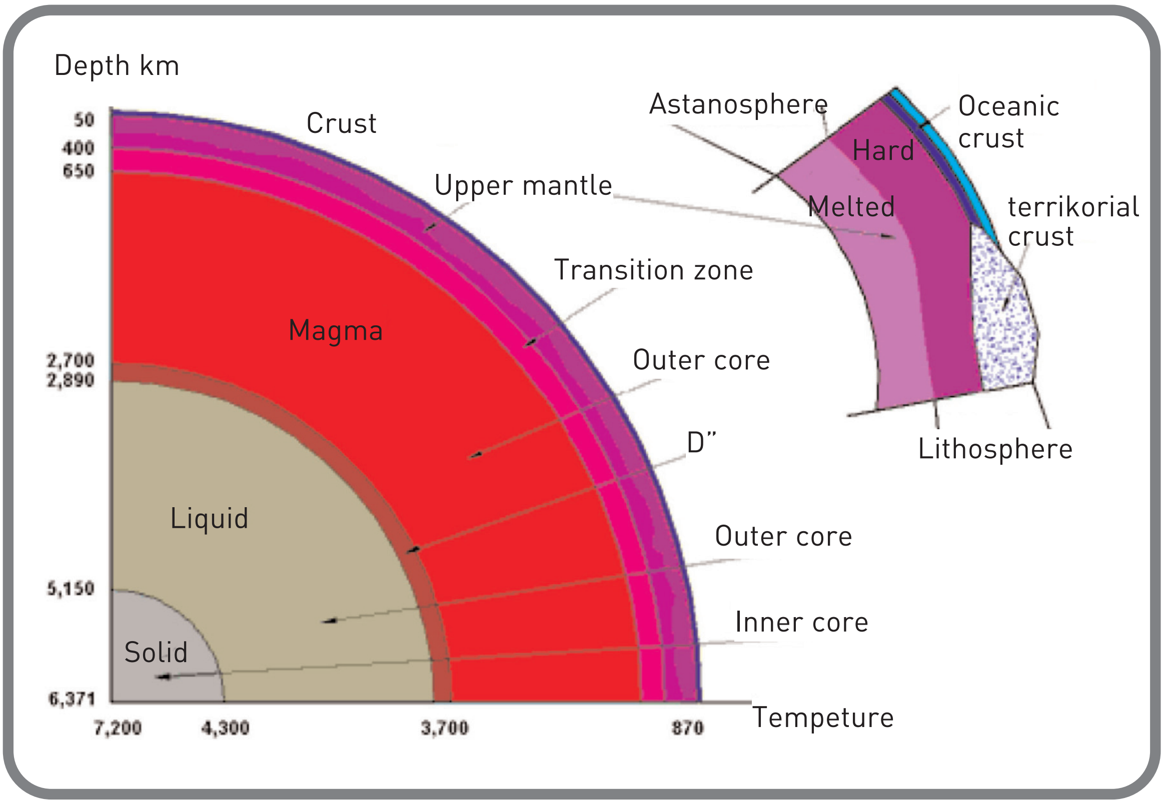



**Figure 1.** The inner parts of the Earth.

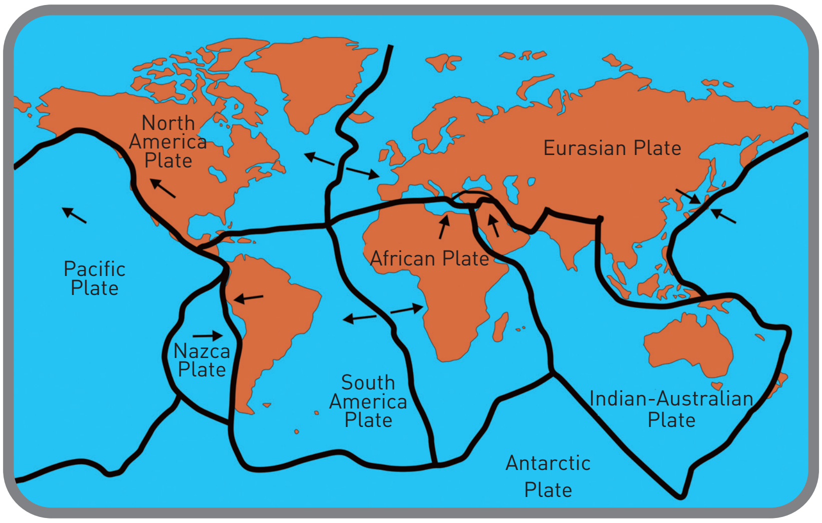



**Figure 2.** Tectonic plates and fault zones.

There are 10 plates and some small plates in earth. The plates are on asteneosphere with the continents that moves without effecting human being.

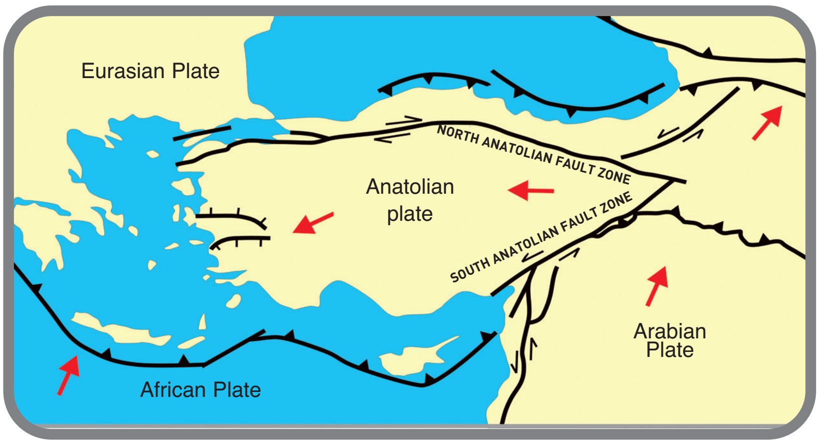



**Figure 3.** Anatolian Plate movement.

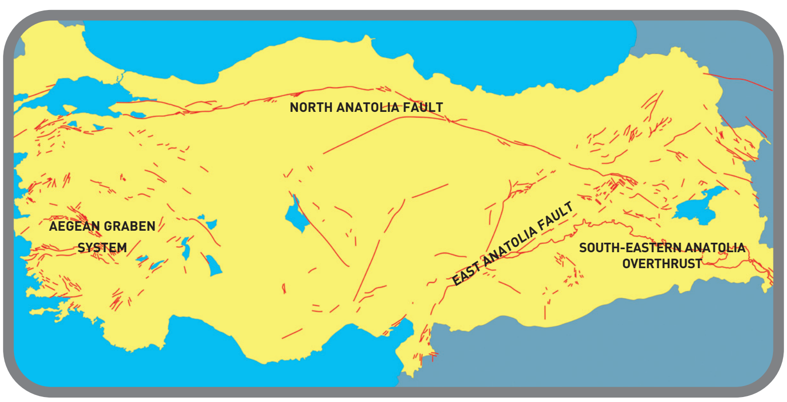



**Figure 4.** Fault map of Turkey.

Earthquakes occur in the connection zones of plates. The main plates are Pacific, African, North American, South American, Euroasian, Indian, Antarctica, Australian. Because these plates moves 1 cm to 10 cm according to each other, people can not feel the movement. It can be measured precisely by GPS (Global Positioning System) that works connecting to satellite.

Turkey is located on the Anatolian plate which is between African, Euroasian and Arabic plates move west-south west direction. The fault that separate Anatolian and Euroasian plates is called North Anatolian Fault. The fault between Arabian and Anatolian plate is known as East Anatolian Fault.

Faults are named according to its movement direction. Faults which have Lateral movement are called strike slip fault. The North Anatolian Fault is an example of this type of fault.

Normal faults are occurred between plates that diverge due to tension force. The faults that moves in vertical inclination that is due to pressure force is called Reverse fault. Himalayan mountains in north of India were formed due to this reverse fault.

The collapse of a block between normal faults is called graben and arising between two normal faults is called horst. Most of the faults has lateral and vertical movement.

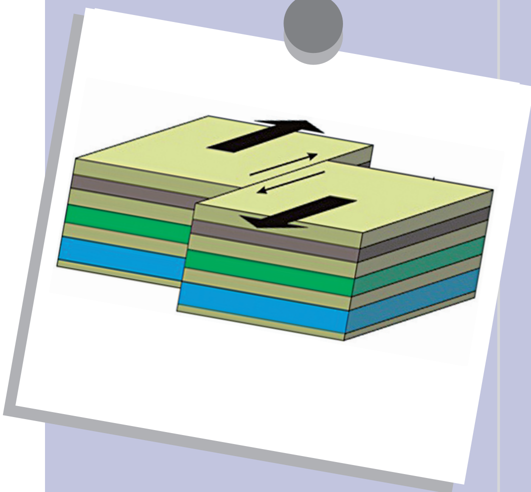


**Figure 5.** Strike-slip fault.

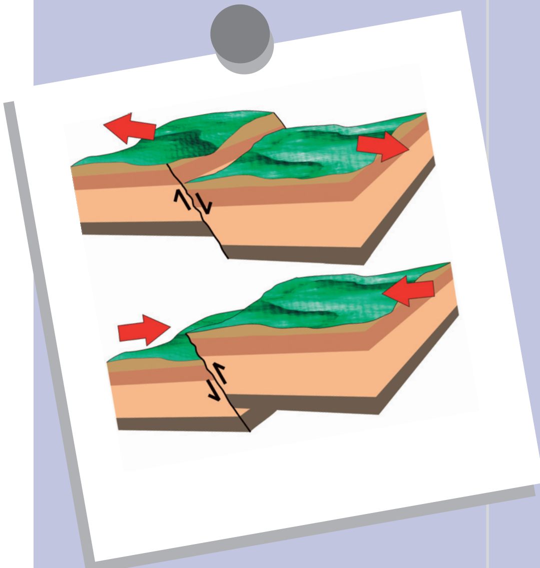


**Figure 6.** Normal and Reverse Fault.

# BASIC EARTHQUAKE PARAMETERS

Earthquake waves are occurred in faults in certain depth due to sudden movements. When these waves propagate in every direction, their characteristics are changed while passing through the different stratums then reach to the surface.

The starting point of sudden movement in depth is called hypocenter. The projection of this point on the surface is called epicenter. Different waves propagate in all direction from the hypocenter.

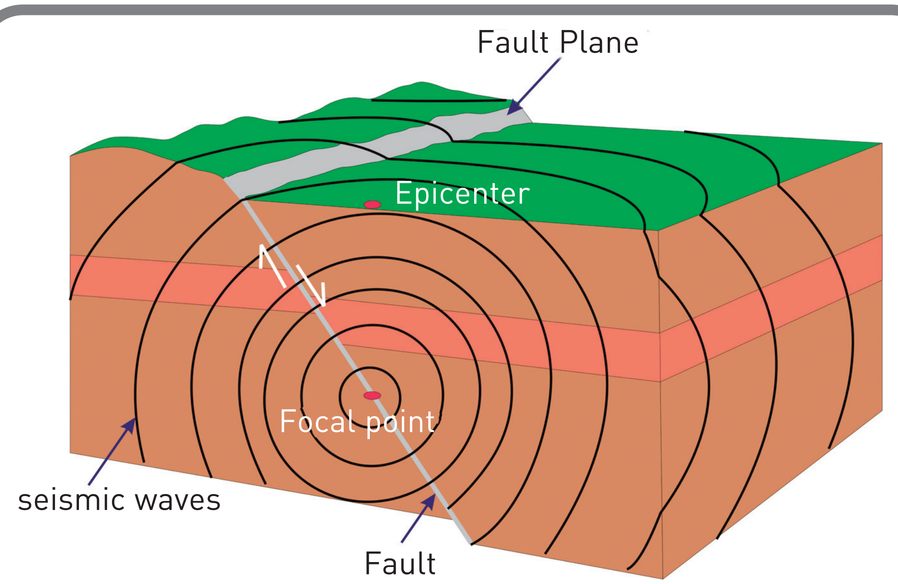



**Figure 7.** Basic earthquake parameters.

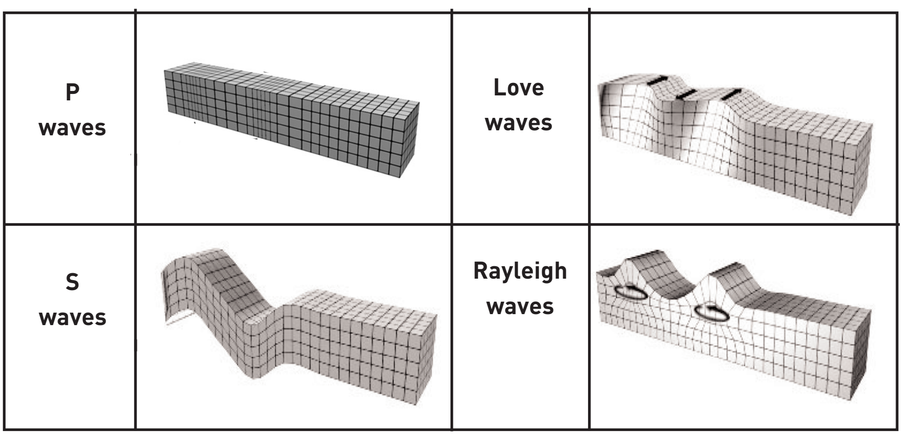



**Figure 8.** Earthquake waves.

The shaking due to earthquake waves is measured by seismographs. There are different measurement scales according to parameters of the waves. Measurement instruments and magnitude of the shaking differentiates based on the measurement scale. The main parameter is magnitude. Because magnitude of an earthquake is measured by different ways there are different magnitudes in one earthquake and these magnitudes can not be compared.

Another measurement of an earthquake is intensity. In early times, intensity was used to classify earthquakes. Magnitude is used to determine earthquake energy by instruments. Intensity is used to determine the effects of an earthquake on engineering structures. There is only one magnitude while there are different intensities in different zones in an earthquake. Thus, magnitude and intensity should not be confused. For instance, there is no intensity where no structure is build.

It should be noted that, effects of an earthquake is related to depth of a fault, to soil stratum that earthquake waves passed through, to fault type, to the distance to center of population, and also to properties of structures. Without keeping this knowledge in mind, it is not true to make decision about an earthquake effect only depending on magnitude value.

For example, in Bakırköy there was rare damage in structures but in Avcılar which is located far away from Bakırköy damage of buildings are more than Bakırköy. NAF creates earthquake near to surface. In Japan, there are greater earthquakes happens but in more deeper than NAF, so the effects of the seismic waves become less. It can be explained by a simple example. For instance a stone thrown to a stationary lake create waves that move in three dimensions and loose its energy. Same as water waves earthquake waves are diminished while passing all layer in three dimensions.

# DETERMINATION OF EARTHQUAKE HAZARD

Strong ground motion shakes structures in all direction. Earthquake resistant design of a building is achieved by determining the probable earthquake in concerned area from fault maps. Earthquake zone maps are classified the zones that are susceptible to greater earthquakes hazard to smaller earthquake hazard. But, these maps must be revised and updated after today's earthquakes.

Turkey is classified in five earthquake zones. Hazard level is maximum in the first zone while it is minimum in fifth zone. Earthquake zone maps are constituted according to faults. It is clearly seen that the first earthquake zones are located near the main faults which have maximum hazard level. This map is included in Specification for the Buildings to be Constructed in Seismic Zones, 2007. Civil engineers build a structure by using this map to determine its earthquake risks.

For instance, to determine earthquake characteristics of a site earthquake zone map is used. If a site is located in first earthquake zone, it means that it is susceptible to great earthquake. Then it is designed according to calculated earthquake forces. So, it is not important that a building is located in fifth or first earthquake zone. All buildings are designed to be earthquake resistant.

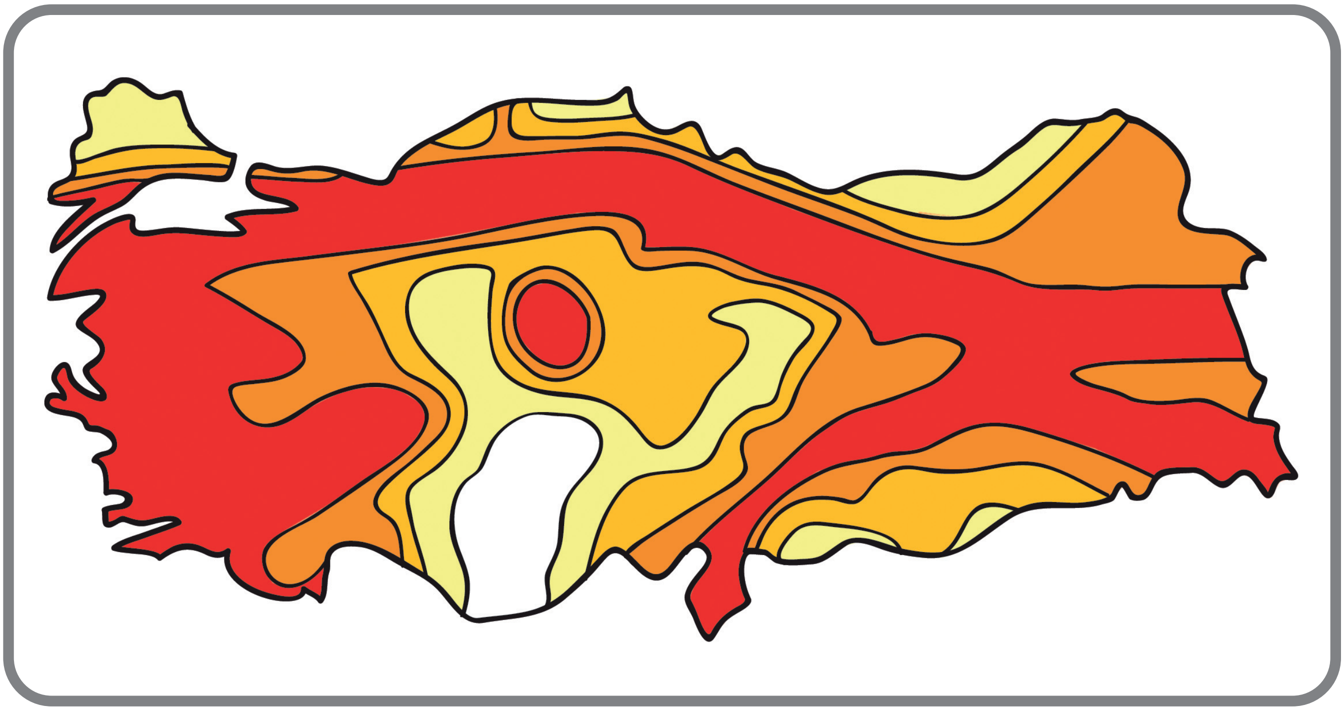


**Figure 9.** Earthquake zone map of Turkey.

# TYPE OF STRUCTURES AND FEATURES

Structure can be explained as an engineering product that is designed to resist all kind of loads by special material used in special type of structure system for a special use.

Structures can be classified according to materials as;
- Reinforced concrete structure
- Steel structure
- Wood structure
- Stone structure
- Adobe structures

Load carrying systems of the structures are;
- Frame system
- Shear wall system
- Frame-Shear wall system
- Masonry system
- Mixed

Majority of the Turkish building stock consists of reinforced and masonry structures. Detailed information about these structures is given in following chapters.

# STRUCTURAL ELEMENTS AND THEIR FEATURES

To achieve building purpose of a structure, firstly it must have sufficient strength. This strength is constituted from load carrying system. A load carrying system is comprised of all the elements that resists to loads. All of the elements in this system is called load carrier and other elements instead of load carriers are called non-structural elements This differentiation is up to civil engineer and his/her design.

In reinforced concrete structures, columns, shear wall and foundation are elements of load carrying system.

In masonry buildings, infill walls carry the loads and it can be made by different materials. Bricks that separate the rooms.

**Figure 10.** Load Carrying systems for Reinforced concrete structures.

**Figure 11.** Load Carrying systems for Reinforced concrete moment frame– shear wall system.

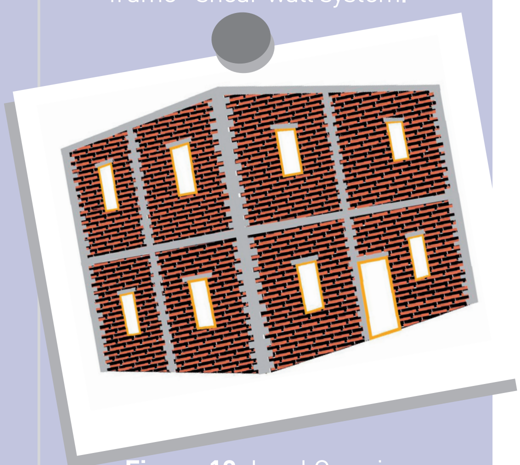


**Figure 12.** Load Carrying systems for Masonry buildings.

**Figure 13.** Load Carrying systems for Mixed System.

## Load Carrying Elements and Systems of Structures

According to structure, load carrying systems in a building are composed of column, shear wall, beam and foundation masonry walls. Column, shear wall and masonry walls are the vertical elements whereas beams are the horizontal elements in a building. It is used together to make a load carrying system.

**Frame system:** Load carrying elements are column and beams which are used in mid and low rise buildings.

**Shear Wall System:** Load carrying elements are only shear walls which are used in high rise buildings.

**Shear Wall-Frame System:** Load carrying elements are comprised of column, beam and shear walls which are used in high rise buildings.

**Masonry System:** Load carrying elements are only masonry walls which are used in low rise buildings.

**Mixed System:** Load carrying elements are masonry walls and wood elements which are used in mid and low rise buildings together.

## Loads Acting on Building and Load Transferring System

Loads acting on buildings can be classified in two groups with respect to load acting direction and be classified three groups according to the load acting type.

According to load acting direction, loads can be in horizontal or vertical direction. Vertical loads are in gravitational direction. Horizontal loads are perpendicular to vertical loads.

According to the load acting type, loads are separated as dead loads, live loads and external loads.

Dead loads are the weights of load carrying elements of a structure itself according to usage purpose, such as self weight of columns, beams, shear walls, and masonry walls. Because dead loads are only the gravitational loads of structural elements, it acts during life time of the building.

**Live loads** are the loads that can be changed according to usage of a building in different times in a lifetime of a structure in different magnitude. For instance, people are working in a building only in work hours. Live loads may act on a building in sometime in gravitational direction.

**External loads** are the loads which frequency and magnitude of loads change according to structure location. Wind and earthquake loads are the representative of external loads that are acting rarely, which the loads are in different proportion with respect to earthquake hazard of a site and in accordance with wind velocity during lifetime of a structure.

Loads are carried according to engineering design. The point is to carry loads as directly as towards soil. Briefly, it is crucial providing continuous load carrying.

system and carrying load in shortest way to the soil. It is depicted in figures that continuous and discontinuous load carrying system. It is clear that much more loads are acting on load carrying elements of discontinuous load carrying system, which will cause trouble.

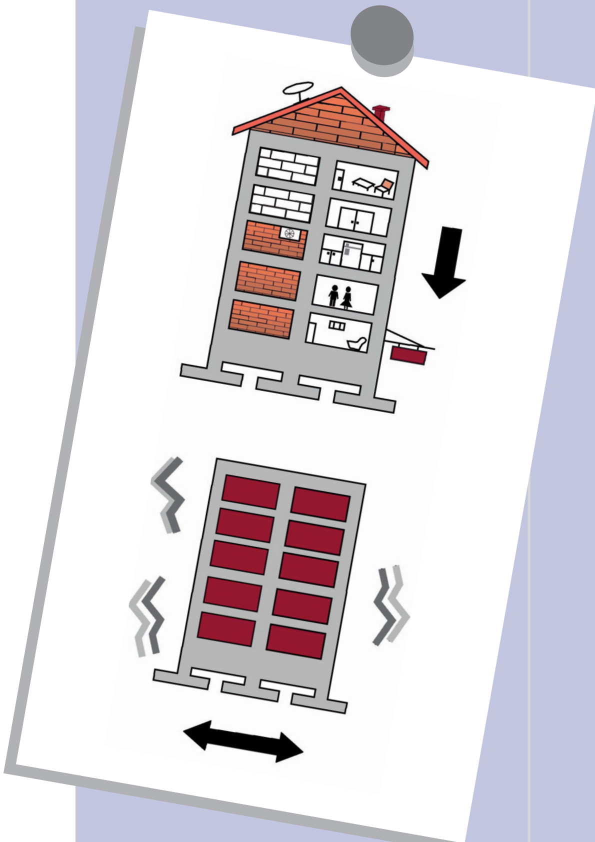


**Figure 14.** Horizontal and vertical loads acting on structures.

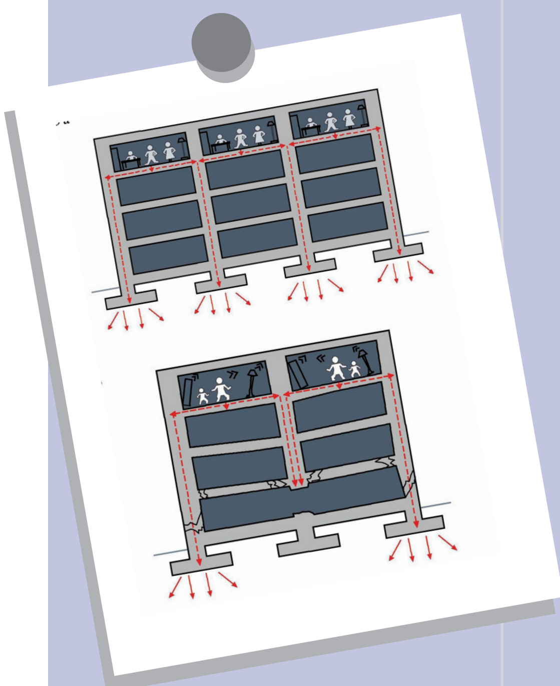


**Figure 15.** Continuous and discontinuous load carrying system.

# BASIC PRINCIPLES OF EARTHQUAKE RESISTANT STRUCTURES

**Figure 16.** Continuous, well balanced and well bounded reinforced concrete frame system.

In earthquake resistant structures, there are some important features that are independent from material and load carrying system. These features should be taken into consideration in design phase and in construction phase. There can be three major principles that is a must in a structure. These are continuity, being well balanced and being well bounded.

In continuity principle, it is aimed that structural elements must be located in one axis without any discontinuity from top to the foundation level. All columns in top floors should be in same coordinate as in lower floors.

The main purpose in well balanced principle is to place load carrying elements of a structure symmetrically in the plan.

Well-connected principle suggests that load carrying elements of a structure must be confined as possible as in all direction or at least in two directions with beams.

Behind these, there are any other principles in earthquake resistant design which is explained in the following chapters.

It should be highlighted that earthquake resistant design has lots of chains of rules which are interdependent. Moreover, required importance to these rules should be taken into consideration. Otherwise, the chain will break up from the weakest chain in which it causes to loose counter measures for the earthquake resistant design. Thus, earthquake resistant structure can only be obtained by well practicing and maintenance, and obeying the rules under supervision of group of professionals.

# REINFORCED CONCRETE STRUCTURES

The Turkish building stock is mainly composed of reinforced concrete structures. Reinforced concrete elements are made by placing rebars into concrete.

Ancient earthquakes show that reinforced concrete structures are vulnerable to earthquakes. The main reason is uncontrolled construction by unprofessional persons, usage of poor quality material, and improper design. As it is told before, any cracks in earthquake resistant design chain rules is end up with life and economical loss.

There was 52000 building was damage in 1999 Kocaeli and Düzce Earthquakes which cause great amount of life and economical loss. 70% of them had medium damage, 25% had heavily damaged and 5% was damaged like pancake whereas damaged buildings became unusable.

## Elements and Functions of Reinforced Concrete Buildings

Elements of reinforced concrete buildings can be separated into two as load carrying element and elements that are carried. Columns, beams, shear walls and foundations constitute load carrying elements whereas floors, walls and roofs constitute elements that are carried by load carrying elements.

Load carrying elements and its features are summarized as

- Columns are vertical elements and used in low and medium rise buildings with shear walls.
- Shear walls are thin columns which has seven times greater length than width of it.
- Beams are horizontal elements which confine columns and shear walls to make the load carrying system well bounded.
- Foundations are the elements which carry the loads of structure to the soil.

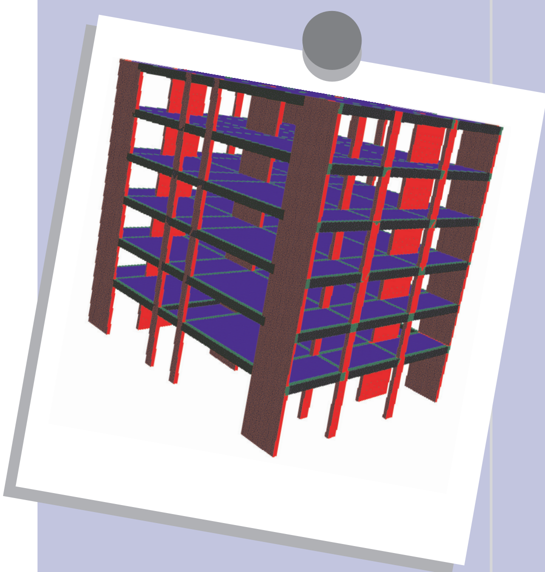


**Figure 17.** Scheme of reinforced concrete structure.

Other elements that compose a structure and their properties are

- Floors carry the loads that are in the structure such as people, furniture etc. and transfers it to the beams. It has small thickness compared to dimensions. In other words, the place that we walk on it.
- Infill walls separate the rooms according usage purpose and also have a role in sound and heat isolation which are made of hollow bricks.
- Roofs isolate buildings from rain, snow and heat in different material and in different geo metric shapes.

## Factor Affecting Earthquake Performance of Reinforced Concrete Structures

To stand safely, earthquake resistant buildings should have the main principles of continuity, being well balanced and being well connected as written below. Lack of any of these principles affects earthquake performance of buildings adversely.

Both misapplications because of wrong design and usage requirements unfavorably influence earthquake performance of buildings. Problems that may happen in case of this kind of problems and countermeasures are explained in the following sections. The main factors affecting earthquake performance of a building are:

- Soil condition
- Geometry of the building
- Soft storey
- Short column effect
- Adjacent building

**Soil Condition**

Soil has a great importance due to being the first transferring point of earthquake waves and element of a structure that touches to the ground. Soil properties of a site are the key parameter to decide foundation type of a structure.

Design engineers calculate how the structure will be affected according to local site condition obtained from soil survey and geological maps and earthquake hazard maps.

Surface of the earth is covered by natural deposits like soil and rock. Soil have become during 4.6 billion years of formation process by the effects of heat differences, ice, wind, pressure and chemical process. These natural processes cause decomposition of soil, erosion of soil particles, transportation of soils, sedimentation of soil. As a result, soil particles and voids between particles are composed soil. Also voids can be partially or fully filled up with water.

Soil is comprised of different size of particles that can be classified in four according to its particle size which are gravel, sand, silt and clay, relatively.

Earthquake waves altered while passing through soil layers in which it can be amplified or deamplified according to its energy. Unfortunately, there was a misunderstanding that soil are charged for all the devastating effects of 1999 Kocaeli Earthquake. But, soil reacts different in every earthquake.

Earthquake forces are felt as a fast shaking in hard soils while shaking is felt in longer intervals in soft soil. Earthquake waves travel fast and with short interval in rock. In soft soils, waves travel with longer period. In great earthquakes, earthquake energy is de-amplified despite of soft soil.

Lower rise buildings shake with high frequency. Due to low rise building constructed on rock site shakes with high frequency cause to have more damage. Moreover, because of high rise building on soft soil shakes with lower frequency, which shakes longer period, cause high damage.

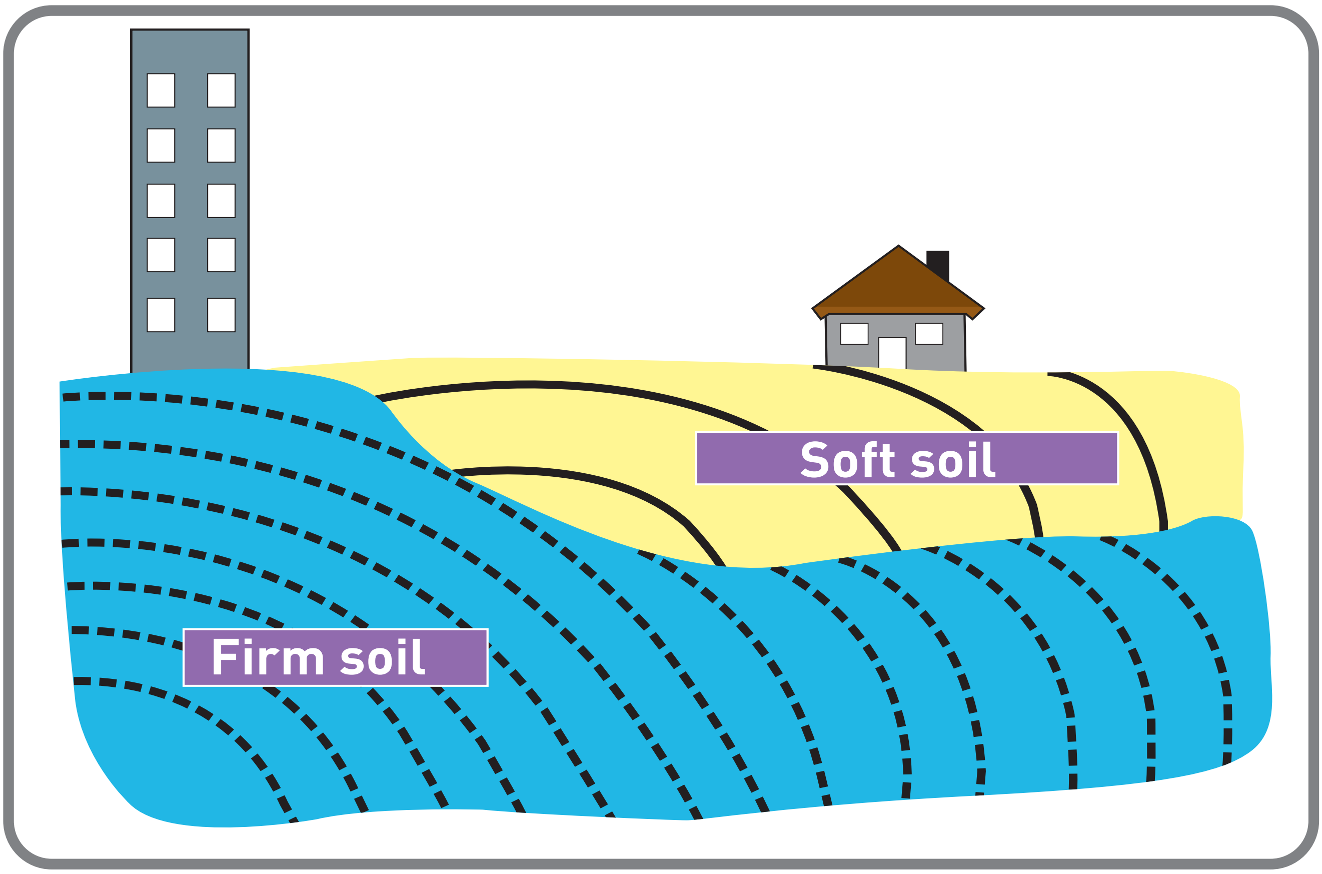



**Figure 18.** Earthquake waves behave different in different soil.

As written below, a building without engineering design constructed on rock site can not be safer than a building constructed by engineer on soft soil. Consequently, the main rule for the earthquake hazard mitigation of construction of public and government is construction in accordance of soil parameters.

**Geotechnical Information**

Geotechnical parameter of a site is needed to calculate how the soils react. For every building, there must be own soil survey to identify soil layers. In the light of this information, earthquake forces that will hit the building can be calculated, and earthquake resistant buildings can be constructed.

In microzonation studies, a site is divided into squares and soil survey is conducted that will be representative of the cell in order to achieve microzonation maps and inhabiting convenience maps. In these maps, liquefaction and landslide susceptible prone areas are identified. Civil government can allow or prohibit construction on those sites.

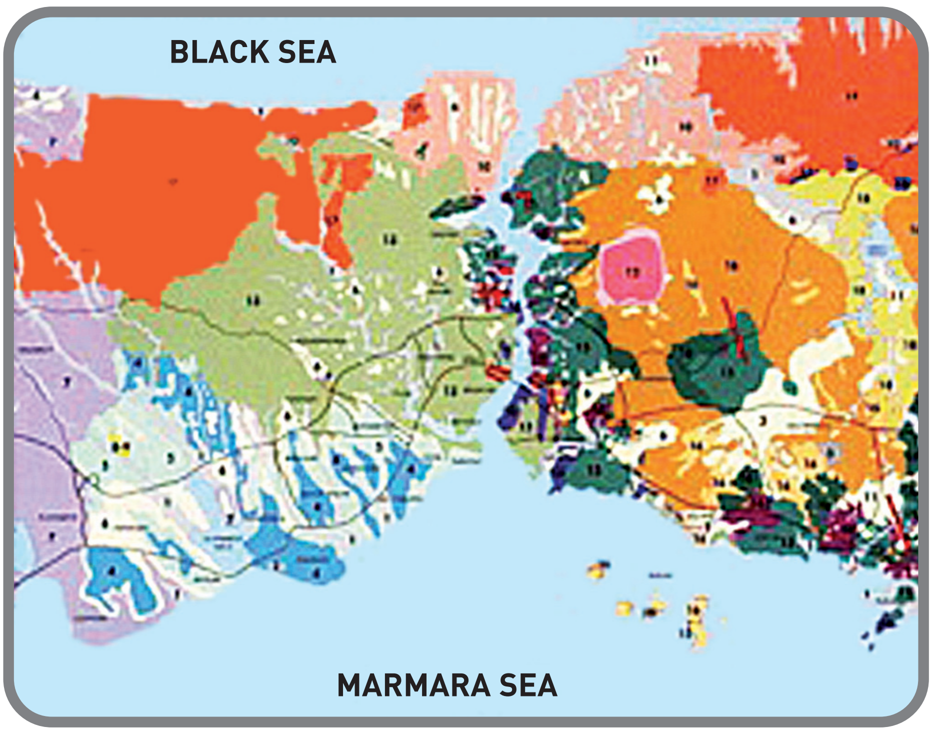



**Figure 19.** Geological map of Istanbul.

Settlements can be observed on structures on loose, uncompacted and zones that inappropriate soil improvement studies conducted. It is more likely to see damage on structures when an earthquake happens. Fault zones, on steep slopes, on swampy areas, liquefaction and landslide prone areas are unfavorable areas to be constructed on.

Engineering design of a structure need some information such as closeness of a structure to fault, magnitude of the earthquake that may happen in that site, engineering properties of layers of soil. In consequence, soil is one of the chains in earthquake resistant design.

**Liquefaction**

Liquefaction is likely to occur in loose fine sands and some silty soils which are layered under water table in a site. When the earthquake waves arrives to the site, soil particles are forced to be compressed that will causes the water to squeeze out due this pressure. After the compression of soil, water takes all the pressure till the soil loose all its bearing capacity. Then soil behaves as a liquid.

The results of liquefaction can be observed during or after an earthquake. sand boiling which can not be observed in every earthquake is a proof of liquefaction. The water comes out by taking the soil particles while passing the layers. It is dangerous to build a building in such areas. Buildings may sink or tilted due to liquefaction. Structures can be built on such site only if soil improvement techniques are applied to the site, by lowering the underground water table, by transmitting building loads by installation of pile foundations under a structure.

In code, if the underground water table is in 10 meters depth, in D type of soils, it must be explored by geotechnical investigations whether liquefaction is likely to occur or not.

**Foundations**

Foundations are the elements of buildings, which are built for education, health facilities etc., to transmit the vertical loads of dead loads such as carrying elements of building, live loads such as living objects such as furniture, some equipments, horizontal loads such as earthquake and wind loads to the ground. It

**Figure 20.** Damage of a building due to liquefaction at Adapazarı, 1999 Kocaeli Earthquake.

**Figure 21.** Bearing Capacity Loss of Soil and Settlement of a building due to Liquefaction.

**Figure 22.** Examples of Single and Continuous Foundations.

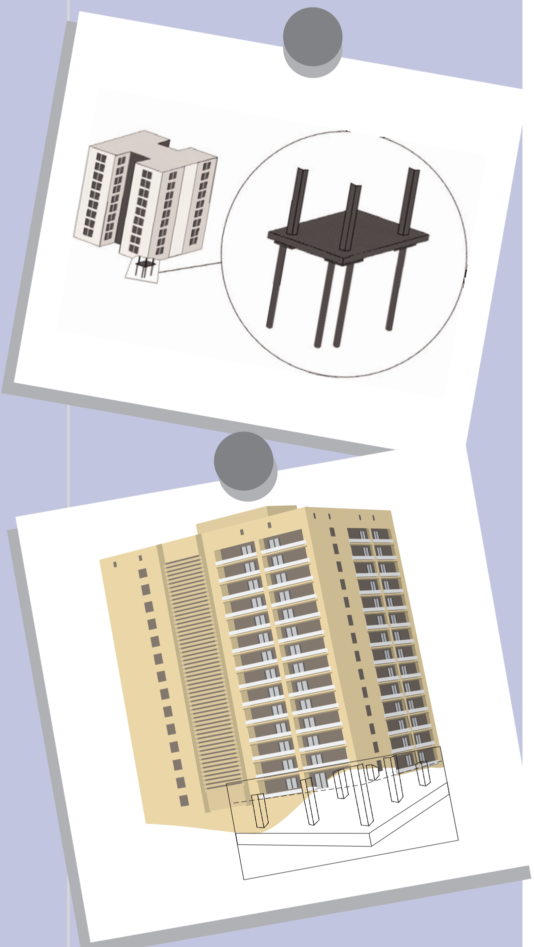


**Figure 23.** Examples of Mat and Pile Foundations.

is transferred safely to the ground by preventing soil collapse, and extreme settlement. Foundations are structural elements that are built in different sizes according to site conditions, and to loads acting on buildings.

Foundations must be built for not only the loads acting buildings but also for the soil conditions. To carry the loads safely it must be transferred to wider areas in soils of low bearing capacity. Thus, the effects of load are reduced by expanding the foundation sizes. Wider foundations are needed in buildings settled on soft soils.

In practice, different types of foundations are built according to soil conditions and loads acting on buildings. These are as follows.

- Single Foundations
- Continuous Foundations
- Mat Foundations
- Pile foundations

Single foundations are built under low rise buildings of one or two floors located on hard soils. Foundations are built under every column such as foot in a human body. Human body is carried by skeleton system and the loads are transferred by feet to the ground. Foundations are connected by beams to prevent different settlement of a building.

If the loads acting on buildings are higher and soils conditions are softer then continuous foundations are built. In this type of foundation, the length of foundation has to be extended to the neighbor foundation that is formed a continuous foundation from one column to the other column.

If the site is layered by softer soils and/or the loads acting on buildings are higher then the foundation size must be enlarge in every direction. Mat Foundations are built like a floor under building which are thicker than the floors. In other words, all the sitting area of a building is formed as a foundation.

Pile foundations are built if the mat foundations are insufficient to transmit the loads safely. It is built under mat foundations to transfer the loads to the hard layers by passing the soft layers. Pile foundations are formed like a column in the soil which are made up of reinforced concrete, steel or wooden. In Turkey, they are installed by hammer or constituted in situ conditions.

**Foundation Depth**

Foundation depth differs according to building load, soil condition, and design criteria of settlement. The water between soil particles can be sucked by capillarity forces and can be frozen according to weather conditions and dissolved again in hot warmer conditions. The freezing and dissolving recycle may have adverse affect the soil and the foundation. It must be in depth of 0.5 m to 1.5 m according to zones to avoid the adverse affects of the recycle.

Also, foundations must be isolated by petrochemical elements to prevent corrosion in rebars of foundation due to water in soil. Underground water level must be lowered by drainage techniques and surface water must be obstructed to reach foundation. One of the malpractices of drainage system is, rain water is left free to the ground. Thus, the water isolation of base floor and foundations are very important.

Because foundations are designed according to loads acting on buildings and to soil conditions, it is another important member of a chain of an earthquake resistant design. The loads are safely transferred to the ground as a result of engineering design if the soil conditions and properties of structure elements are taken into consideration. It is not needed a mat foundation or pile foundation for every building. So there is no any superiority of a foundation system from another one. It is more pro-

**Figure 24.** An example of wrong designed foundation and a building built without sufficient soil investigation.

fitable to spend for the workmanship and for the quality material than unnecessary building of bigger size of foundation.

### Geometry of Building

The geometry of a building in plan and in vertical axis is another key parameter of earthquake resistant design. The behavior of a building under seismic excitation is geometry of a building. The length of the building in every direction should be similar especially symmetrical in two direction to behave well under seismic shaking such as buildings that have square or rectangular or circular plan.

Buildings that have L, T and H shape will have damage on the corner points the plan due to higher forces.

Unfortunately, unsymmetrical buildings are built in practice due to public works, plot of plan and architectural concern. In these type of buildings, It is advised that plan of the buildings should be divide into squares or rectangular to constitute separate buildings. It just be pointed out that separation part of the buildings may touch each other while seismic shaking. So there must be blank area which is called dilatation.

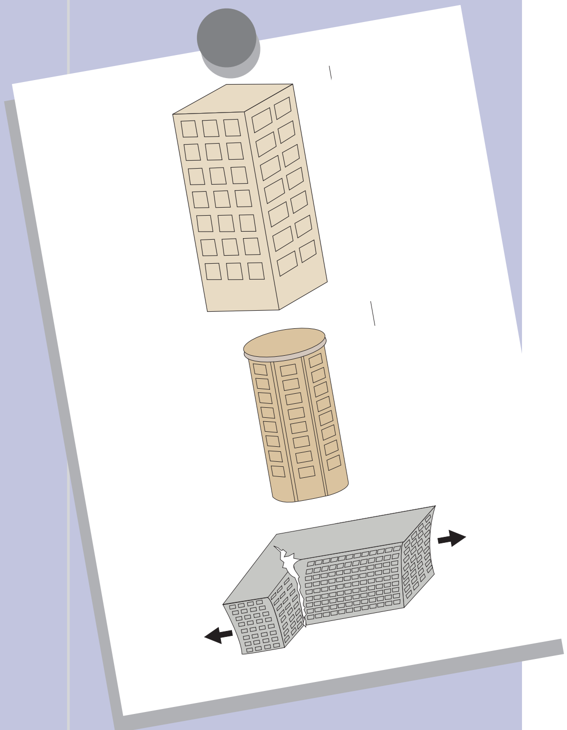


**Figure 25.** Buildings with appropriate and inappropriate geometry.

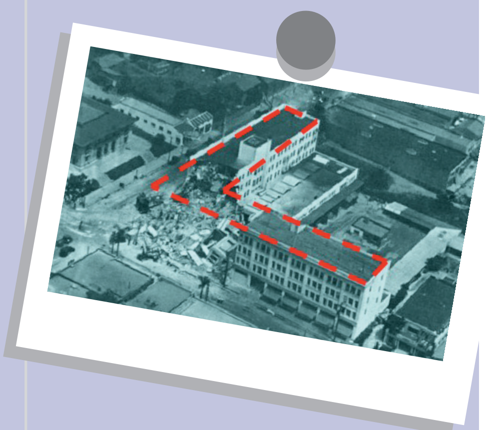


**Figure 26.** Earthquake Damage on a L Shape Building in 1906 San Francisco.

## Soft Storey

Infill wall placement may constitute soft storey phenomena in earthquake behavior of a building while it has no load carrying capacity. Soft storey occurs in discontinuity of infill walls in frames systems.

Unless infill walls placed in same position in every floor, horizontal load carrying capacity of building becomes lower. For instances, the basement of the buildings in Turkey are built for shopping that causes soft storey on that floor.

Rooms are separated by infill walls or plaster panels which are widely used in nowadays. Infill walls make a

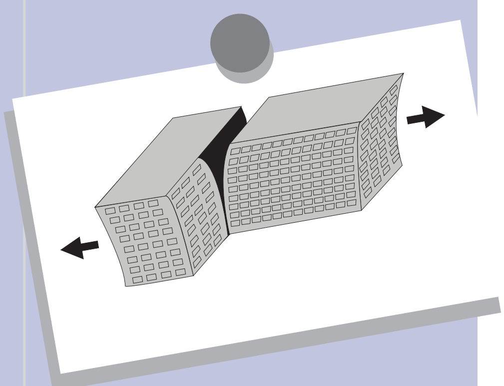


**Figure 27.** Buildings separated by dilatation.

little bit contribution to the horizontal load capacity of buildings by acting as a shear wall while they have no load carrying resistance. Acting as a shear wall may cause rigidity of the building. Rigidity is the strength that can be defined by material property and geometrical property. Columns bend due to seismic shaking in accordance with its capacity. Because column has restricted bending capacity, shear cracks will occur in joints.

In financial buildings, infill walls between columns are extracted to have more free space but it there are still infill walls in upper floors which give contribution to the columns. When an earthquake happens, upper floors make lower horizontal displacement while the base floor makes higher displacement. In this type of basement floor are called storey. As it is seen in Figures, if infill walls are placed between all columns in every floor, horizontal displacement of all floors will be equal. In case of the lack of infill walls in basement floor, the horizontal displacement will be height according to upper floors which will cause the basement floor to make whole horizontal displacement of the building.

The effect of infill walls to the earthquake behavior of the building is important. One of the precautions can be taken to prevent soft storey is placing soft material between column and wall to detach infill walls from columns. Thus, all columns in all floors behave same and no soft storey will occur.

Another proposal to prevent soft storey is using a soft material that can be broken during seismic shaking. However, heat and sound isolation problem may occur.

Infill walls installed from hard material that can be broken and fall which cause economic and life loss during an earthquake. Thus, infill walls can be covered thin wire before the plaster and connection of columns and walls should be made carefully.

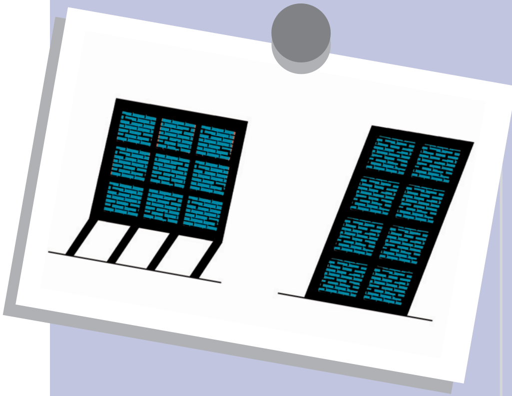


**Figure 28.** Earthquake behavior of a building with infill wall discontinuity.

**Figure 29.** Building Damage due to soft storey.

**Figure 30.** Frequent misapplication: Lack of Infill wall in basement floor.

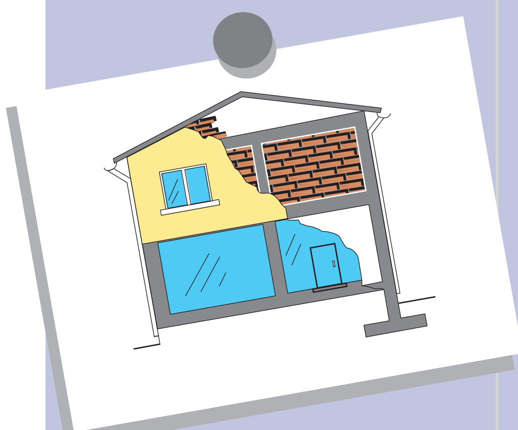


**Figure 31.** Countermeasures to prevent soft storey.

Figure 32. Typical damage in infill walls.

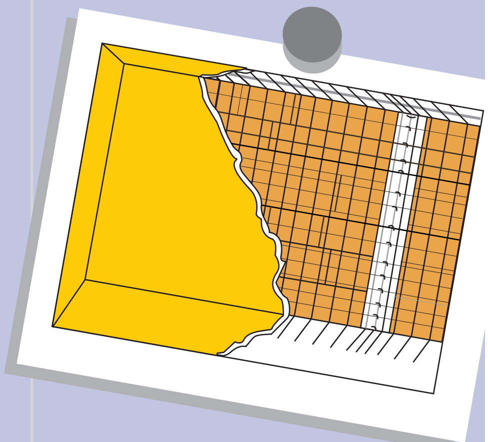


Figure 33. Proposed precautions for infill walls.

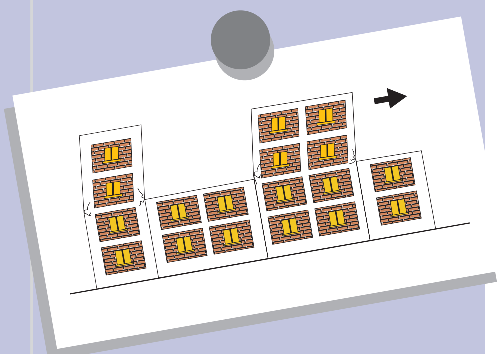


Figure 34. Same floor levels in adjacent buildings.

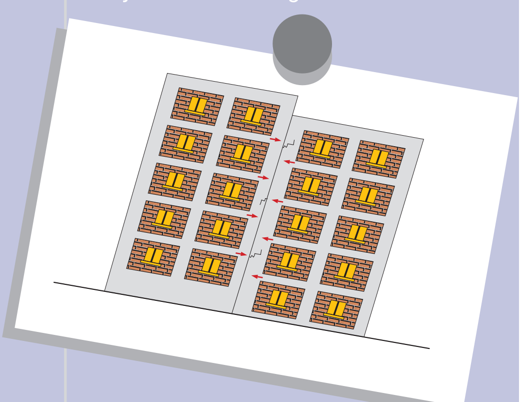


Figure 35. Different floor levels in adjacent buildings.

Usage of a building is very important issue. Users may remove infill walls to obtain more free space which cause soft storey on that floor and affect earthquake behavior of a building adversely.

**Adjacent Building**

Not only have the properties of the building but also an adjacent building affected the earthquake behavior of a building. When an earthquake strikes, all buildings sway according to its load carrying system, cross section of column and beam, position of structural elements on a plan. Therefore, adjacent buildings may have problems. In Turkey, being parcels mostly close especially touching each other cause buildings to be built adjacent.

The levels of floors are same or different has different effects. If the level of floors is different, floor of one building is on the mid-level of other building which may cause building to be damaged. On the other hand, floor levels are same but the height of adjacent of buildings may be different. This will also affect the sway period of the buildings. To prevent adjacent building effect, public works of parcel should be changed and adjacent building should be prohibited.

However, this prevention proposal is hard to apply due to economic and law problems. Another proposal is to leave some dilatation between adjacent buildings which the limits are in code. The minimum dilatation limits is 30 mm up to 6 m height building, and it must be added 10 mm for every 3 m height after 6 m limit.

**Short Column**

In design process, being some column heights is shorter is called short column. Them main reason for this is some of the columns are confined by different floor at different height of the column. The other reason is the infill walls that are upto different height of column. The short part of the column behaves different than the other columns. Then more forces acting on short columns than its predicted and damage is likely to occur.

At ladder connection points and slide window space on infill walls cause to short columns. The main precaution to avoid short columns is leaving space between column and infill walls that will help columns to sway freely. Also, determining the probable short column locations and taking precautions such as locating appropriate rebars in appropriate application is another measure.

Another point must be focused on is all the buildings with short columns may not be damaged in an earthquake. If it is determined during design process measures can be taken to prevent from earthquake damage. In other words,

buildings on soft soil, with unsymmetrical plan, with short columns can be designed and built according to code. Then probability of damage of building due to earthquake can be decreased. As a result, it is anticipated that building designed by engineers behave well in earthquake.

**Construction of Reinforced concrete Buildings with Proper Material**

Even if it is designed by engineers in accordance with the Code, there may be problems in case of misapplication during construction phase. Therefore, construction and maintenance phase are also important processes.

Reinforced concrete is comprised of concrete and reinforced by rebars. Cement, water and aggregate which are sand, and gravel added in special ratio is the components of concrete. Rebars are factory productions that are classified according to carbon content. In Turkey, production of rebars and concrete is regulated and controlled by codes.

**Figure 36.** Damage due interaction effect of adjacent building.

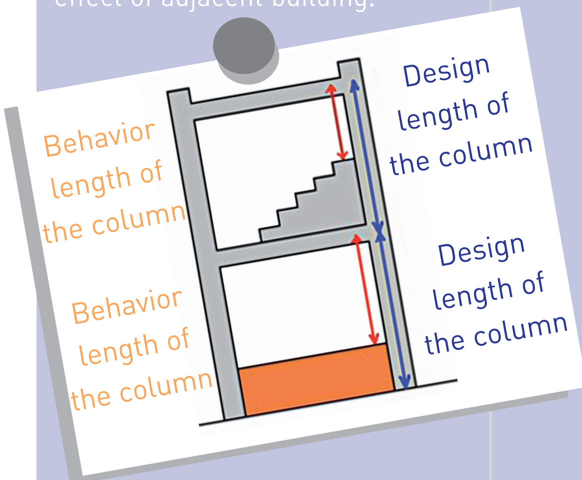



**Figure 37.** Schematic view of short column.

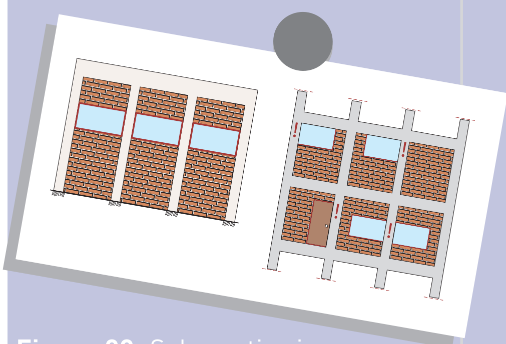


**Figure 38.** Schematic view of short column.

**Figure 39.** An example of short column.

**Figure 40.** Construction with Ready-mixed concrete.

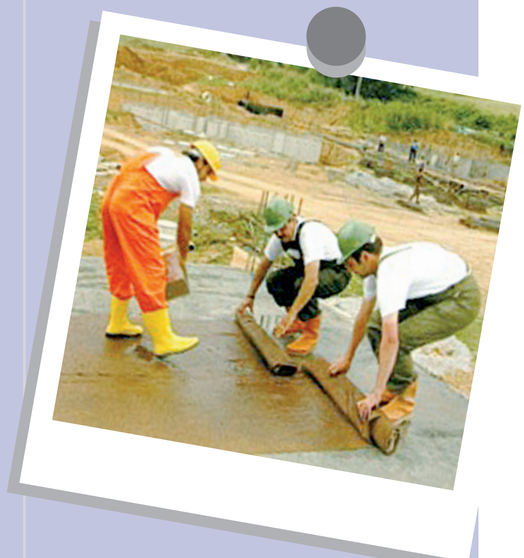


**Figure 41.** Covering of concrete with wet textile for curing.

**Figure 42.** Ribbed or plain rebars.

Observations from past earthquakes indicate that concrete qualities of the current buildings are under limits of the Codes. Strength of concrete of a current building may decrease depending on environmental effects and economical life of building. The main reason of poor quality concrete is misapplication and uncontrolled concrete production.

Especially people who build his own building use poor quality concrete that makes it prone to be damaged in an earthquake. Nowadays, development in ready-mixed concrete production makes concrete quality better and usage of it has increased. The minimum concrete quality limit in Turkish earthquake code is 20 MPa=200 kg/cm$^2$.

Even if quality cement and aggregate is used in proper ratios, those are not enough to obtain quality concrete. The maintenance by the time concrete reach the real strength is also important issue. Produced concrete must be protected from outer and inner adverse effects.

Newly poured concrete must be maintained to reach its predicted strength which is called concrete cure. This application differs according to production site. Until concrete freeze up, the reaction with water brings out heat which causes to reduce water ratio in concrete section. So it must be stay wet. Unless it is wet, shrinkage cracks will occur and predicted concrete strength can not be obtained. Thus maintenance until it reaches predicted strength is very important.

Another important issue in concrete quality is pouring concrete by the help of vibrator. It is used to reduce air bubbles in concrete section and to help concrete to wrap the rebars. Vibration makes concrete to be placed well in a section. It is also obliged in earthquake code. Also, some chemical additives are used to obtain self compacting concrete.

Reinforcement bars are in two types in Turkey, ribbed bar and plain bars. These have different shape and strengths. Ribbed bar strength is higher than the plain bars and it has some curves on it to enhance pull out resistance.

There are some rules to produce reinforced concrete elements by using quality concrete and rebars. The position and placement of rebars are very important and may cause some problems if the restrictions are not applied.

Reinforced concrete elements have vertical and horizontal rebars in it. Vertical rebars are called longitudinal rebars whereas horizontal rebars are called transverse rebars.

These reinforcement bars have special duty. Transverse rebars which are called stirrup wraps longitudinal bars to maintain concrete core during seismic shaking. It must be placed in special form and space.

In Turkish earthquake code stirrups must have 135 degree of a hook both in columns and beams. Also, stirrups spacing must be decreased at column beam joints that are the most critical points subjected to earthquake forces. Decrease of spacing of stirrups gives ability to building to sway under earthquake forces. Buildings resist earthquake forces by swaying and by the strength of structural elements.

Stirrups that are not produced according to code will not behave as it is predicted and they will open up during earthquake shaking.

Moreover, there must be a 2 cm thick cover concrete after stirrups to protect rebars from corrosion and other environmental effects.

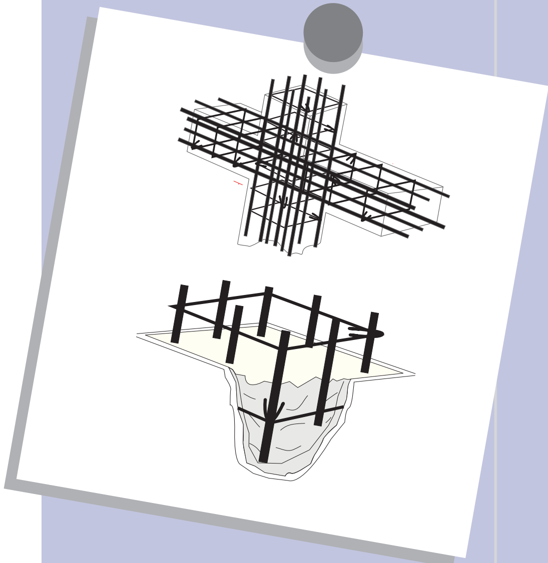


**Figure 43.** Vertical and horizontal rebars in a concrete element.

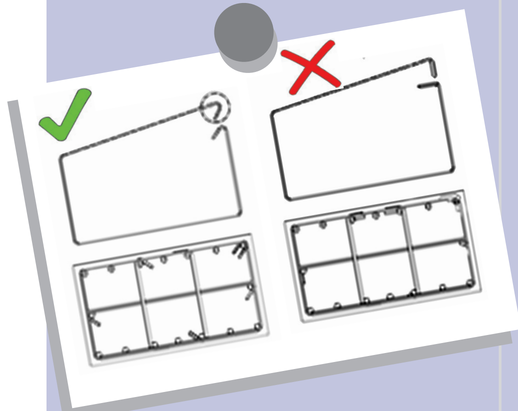


**Figure 44.** Misapplication of stirrups (90 degree hook) and best practice of stirrup (135 degree hook).

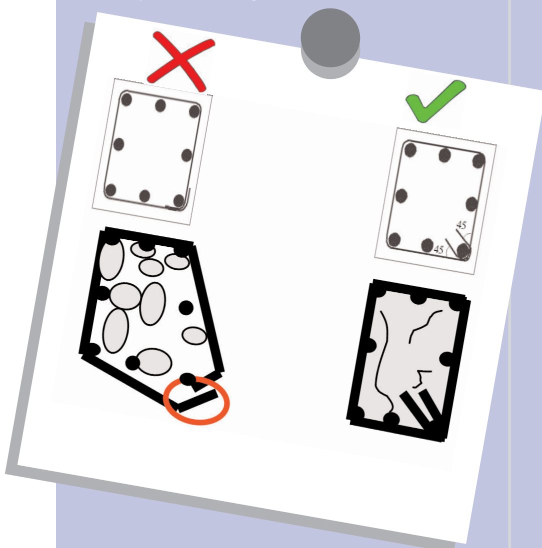


**Figure 45.** Decomposition of reinforced concrete section due to misapplication of stirrup.

**Figure 46.** Column damage due to lack of stirrup and insufficient spacing.

**Figure 47.** A Building ready to add extra storey.

It must be taken care of placing rebars in appropriate quantity and in appropriate position. The placement of rebar needs experience and specialty. It should be understood that producing a reinforced concrete structure is not just an easy application of placing rebars in ones own opportunity. Only the structures built by specialized professionals are earthquake resistant structures. It must be kept in mind that earthquake resistant buildings can be obtained after a particular and an accurate process.

## Maintenance and Protection of Reinforced Buildings in Service Life

As it is in every tool, buildings, which we spend most of our life, needs maintenance. The steps of maintenance of earthquake resistant building are as follows.

**Keeping the geometry of the building as it is:** Adding a storey is one of the misapplication. The predicted storey number must not be changed. Designs of structural elements are achieved according to earthquake behavior of a building. Adding extra unpredicted storey will change earthquake behavior of building.

**Keeping the structural elements as it is:** Changing structural elements or removing them is another wrong practice. They must be kept in same sizes and numbers.

**Keeping the purpose of use of the building same:** Earthquake forces acting on buildings are calculated according to the purpose of use of buildings. Changing the purpose of use may add extra forces which will make structural elements insufficient to resist forces. Unfortunately, some residential buildings are changed to be used as hospital or school without taking precautions, strengthening.

**Adding extra heavy equipment, water storage and other tools:** Adding unpredicted weights of heavy equipment will adversely affect the earthquake behavior of building.

**Water insulation:** Making insulation of a building for inner and outer water keeps strength of structural elements same by protecting from corrosion. Corrosion is a process that steel becomes rusty and loose its thickness due to humidity and air. The designed steel area will be lost due to corrosion.

**Maintenance of the building:** Buildings must be kept same as they are designed and built. The structural elements must be maintained in same size, infill walls should not be removed. Similarly, adding extra elements or weight must be avoided.

**Figure 48.** Corrosion due to outer environment.

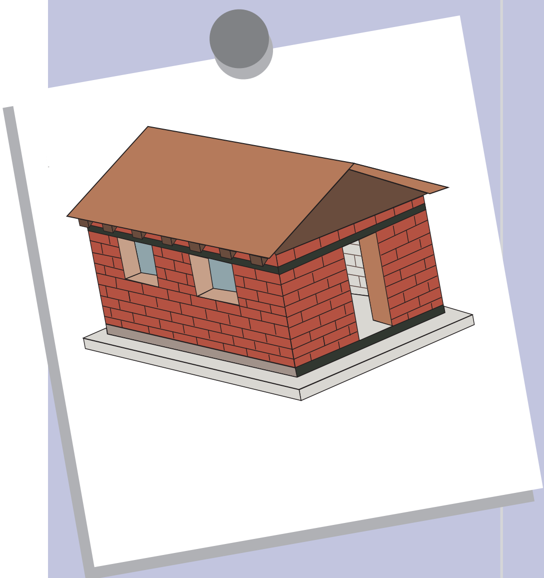


**Figure 49.** Typical masonry building picture.

# MASONRY BUILDINGS

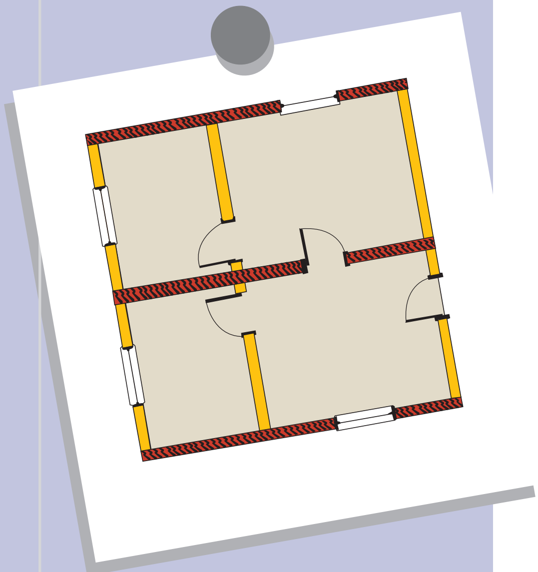


**Figure 50.** Carrying wall placement as symmetrical in two axis.

In Turkey, one of the buildings type widely used in rural areas is masonry buildings. Main element of load carrying system of masonry buildings is walls which are made of different materials. Type of material used often is concrete, bricks and stone. To separate rooms and interior spaces hollow bricks and briquettes are used. Earthquake performance of masonry building in past is not as good. The primary reason for this is production of masonry buildings without engineering services, using poor quality materials, lack of facilities within the region and construction without taking into account the principle of earthquake resistant design of structures. However, it should not be forgotten that earthquake performance of structures which have had engineering services has no problems in term of seismic safety.

## Members of Masonry Buildings and Their Functions

**Figure 51.** Combination of wall connected perpendicular to each other.

Noted above that, the infill walls are the main structural members of masonry structures. However, an element of called "girder" is also a member of load carrying system of masonry structures as the walls of the structure to ensure behave as a whole in an earthquake. Girders which usually made of reinforced concrete are built in vertical or horizontal. But, vertical girders do not have load carrying capacity like column and also horizontal girders do not have load carrying capacity like a beam. The main task of this element is to bind to each other the carrier walls in vertical and horizontal to provide integrity. Horizontal girders are built above the windows and doors where the load carrying capacity weakens to provide strength. They have also an important role on binding all the carrying walls. Vertical girders are applied at regular intervals to give an extra strength to longitudinal load carrying capacity of the walls. They are applied in at the point of weakness caused by the length of the wall, which are over the limits.

## The Factors Affecting Earthquake Behavior of Masonry Building

It is a must that masonry buildings should have also continuity, well balanced and well confined principles to prevent earthquake resistance. Lack of these principles will probably cause damage. The earthquake behavior of any structure can be affected due to misapplication and wrong design. The main factors affecting earthquake behavior of masonry building are.

- Placement of carrying walls and joints
- Space ratio in carrying walls
- Placement of girders
- Storey number

### Placement of carrying walls and joints

As it is noted before, the distributing all structural members of a structure symmetrical as possible on a plan is a positive factor in terms of earthquake behavior. It is also same for masonry buildings. There will be a more resisting capacity in two directions if structural members placed symmetrical on a plan. On the other hand, being well bonded the junction of two perpendicular walls is an important issue. They must be intertwined and be placed eccentric at corners. Also walls must be placed in the same position in vertical. The minimum wall thickness for the two storey buildings is 20 cm.

### Spacing ratios

The ratio of spacing, which left for doors and windows, has an important role on earthquake resistance of masonry buildings. Storey height should not exceed 3 m It is likely to have damage of weakened buildings due to much spacing ratios in walls. Thus, length of spacing and length of spacing between each other is limited in Turkish Earthquake Code.

Unfortunately these restrictions are not obeyed in practice, and having much spaces with unconsciously. It is limited in first earthquake zone in Turkish

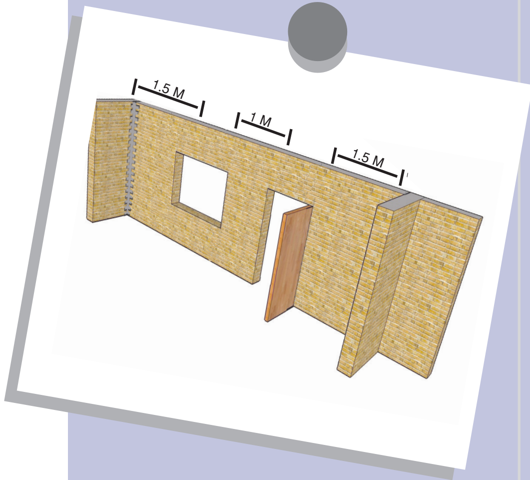



**Figure 52.** Spacing length limitations in masonry buildings.

**Figure 53.** Higher spacing in carrying wall.

Earthquake code that the spacing in unsupported zone of two perpendicular connecting walls should exceed 5.5 m Moreover, spacing between door and window should not below 1.5 m at the corners whereas it is minimum 1 m in the walls.

### Horizontal and vertical girders

Girders are used in weakened points of wall, which are doors and windows, in junctions, which are reinforced concrete members without loading capacity but helps system to resist earthquake forces in terms of binding walls. They can not resist loads like columns or beams. Vertical girders are used in the corner of two connecting perpendicular walls and in walls which has higher span length. Because they are reinforced, it is composed of stirrup and longitudinal rebars.

Horizontal girders are used above the doors and windows, at zones where the load carrying capacity is interrupted. Horizontal girders tied the walls at mid height and at lower height like as a connection to foundation to provide integrity in earthquake behavior. If the wall height is high, horizontal girders are constituted min 2 m below the base to provide unity. The maximum length of wall supported with vertical girders is 16 m whereas unsupported walls length should not exceed 4.5 m there should be reinforcement bars in the girders.

### Number of Storey

It is exceed in practice that storey number limitations are not obeyed. Because the materials of wall have a limited strength and cause to brittle failure in an earthquake, the maximum storey number is limited in earthquake codes. There can be maximum two storey in first earthquake zone, whereas the maximum allowable storey number in second and third earthquake zone is three. Damages are occurred in consequence of exceeding storey number restrictions.

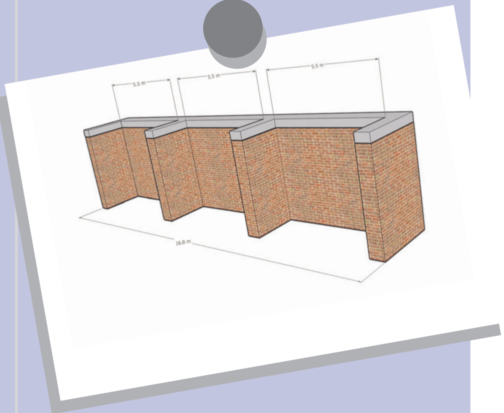


**Figure 54.** Limitation of length of load carrying wall and horizontal girder application.

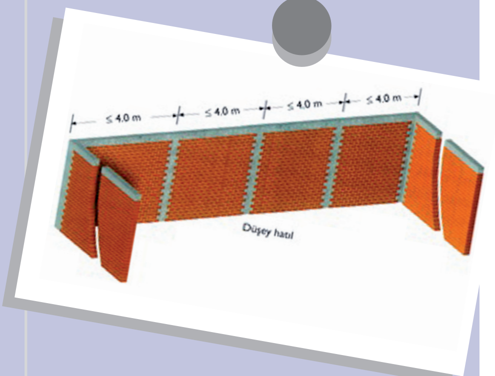



**Figure 55.** Application of vertical girder.

**Figure 56.** Leaving space for the vertical girder.

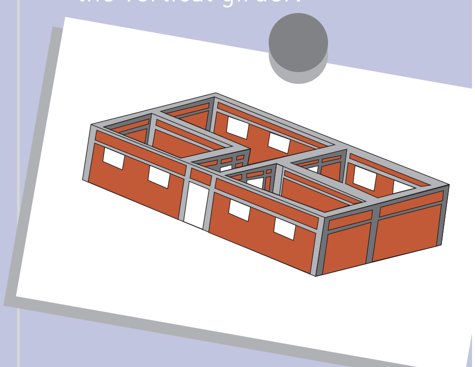


**Figure 57.** Application of vertical and horizontal girder.

## Production masonry building with appropriate material

As it is in reinforced concrete structures, it has to be also in masonry structures that Even if the structures are designed according to principles of earthquake resistant design, damage may can occur during earthquakes.

The main point in earthquake resistant design of masonry structures is quality of wall. Load carrying walls are produced from brick, hollow bricks etc which must be passed from quality control process and complied with the standards. Also registered materials can be used.

The noteworthy point in masonry structures is binding material of bricks. The quality mortar must be used. In practice, only the upper and lower parts of connections are covered with mortar. Also, the vertical connections have to be covered with mortar.

Besides, mortar must be made of appropriate mixture and proportion of water and cement. Bricks must be put up wall special technique which will make the wall behave unique. Also, it must be placed eccentrically in vertical.

Carrying wall must be connected to foundation and roof must be done carefully. Some rebars coming out from the walls may be used as a connection.

## Maintenance and Protection of Masonry Buildings During Service

Masonry buildings need maintenance like reinforced concrete. The main steps are as follows:

**Keeping the geometry of building.** Changing the sizes of the carrying wall is very dangerous. If adding extra wall is needed, same kind of material must be used.

**Water proofing of building.** Materials of wall are susceptible to water. Proofing of carrying walls and mortar is very important. Also, carrying walls must be checked during service.

**Keeping the existing situation of building:** Keeping all the carrying wall size same, keeping the space of window and door same are the key attitudes of protection of buildings.

**Figure 58.** Example to appropriate brick material.

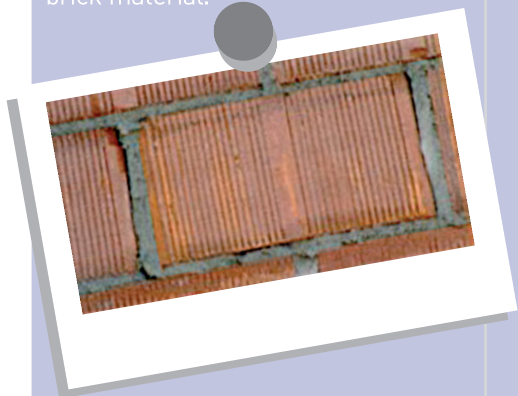


**Figure 59.** Good practice of plaster application.

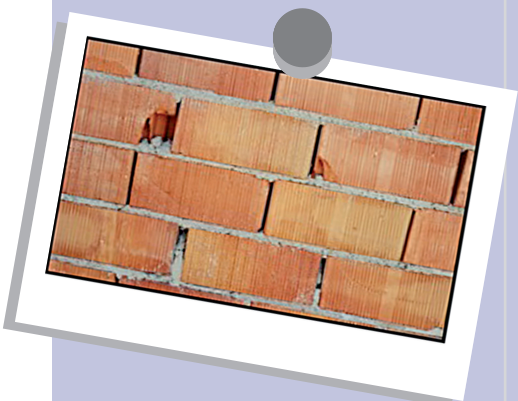


**Figure 60.** Wrong practice of plaster application.

**Figure 61.** Example of masonry wall.

# CONSTRUCTION PROCESS OF STRUCTURES

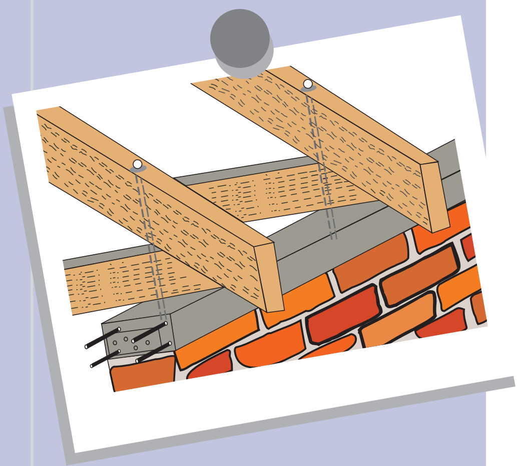


**Figure 62.** Connection detail of roof to carrying wall.

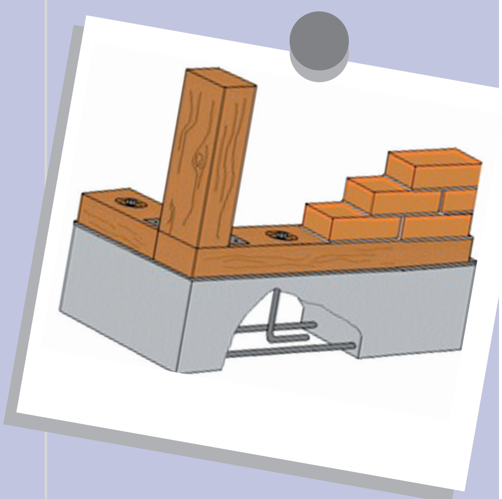


**Figure 63.** Connection detail of foundation to carrying wall.

In this section, process of buildings structure to taking permission and responsible persons and regulations about the process is explained.

Steps of building earthquake resistant structure by a person who has property in land is as follows.

- Preparation of the architectural project according to cadastral extract: There are laws about the buildings which are going to be built on a land. These regulations change with respect to zones, as well as building area, closeness to road, height of building, number of storey. An architect prepares an architectural project considering the needs of property owner.

- Static and dynamic calculations are done by civil engineers in accordance with the architectural project. After soil investigations in the building plot are done, civil engineers proceed to design step.

- Quality control of construction is done by independent building audit firm that is a legal obligation. Property owner must sign a contract with the audit firm to have quality control of materials and construction.

Building audit firm is in charge of controlling all steps of construction. After testing fresh concrete samples taken from every pouring event, they get in touch with municipality to withdraw payment. Municipality officials recheck design project and application then payment is permitted to be paid. Unless it is allowed, audit firm can not withdraw payment.

During construction process, there must be some permission to be taken. The steps of permission is as follows;

- To start construction, building license must be taken from municipality of the construction land.

- After finishing construction of foundation, license of basement must be taken. Municipality officials check whether construction is done in accordance with the design project. Then construction phase can go further to construct upper storeys.

- The last license of usage must be taken after finishing construction. Settling license proceed usage license.

The owner of property, architect give petition for housing license after building audit firm finishes the last controls. Municipality officials make the last control over the project to give permission to water and electricity installation which can be allowed by settling license.

Modification permission must be also taken if needed. There can not be modification without permission. Unconscious modifications may corrupt safety of building. Also, changing usage purpose of building such as changing residential building to be used as hospital, and great modification such as using balconies as a room by covering with wall and window can be only done by taking permission.

Modification of historical buildings can be done by a permission from Cultural and Natural Heritage Preservation Board. This permission is very important to prevent historical buildings.

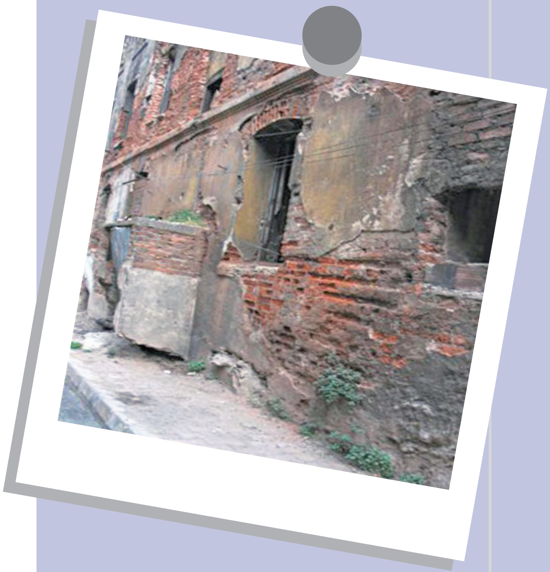


**Figure 64.** Decomposition of carrying wall due to humidity in time.

# COMPULSORY EARTHQUAKE INSURANCE

98% of population in Turkey is located on earthquake zones. After 1999 Kocaeli Earthquake, Decree Law No.587 "Decree Law Relating to Compulsory Earthquake Insurance" entered into force by being published on 27.12.1999 that has given birth to Turkish Catastrophe Insurance Pool (TCIP). TCIP provides residents in a municipality district to be paid for the damage caused by an earthquake. It is a compulsory insurance. Since September 27th 2000, TCIP pays 18.7 million TL has paid for 9608 issue. It must be emphasized that no governmental payment was used for the insurance of earthquake damage.

Insurance premiums are forwarded by insurance companies to TCIP. Dwellings that remain inside the boundaries of the municipality which have official licenses and independent sections situated inside residential buildings but used as small business establishment, bureau and similar purposes are in the scope of insurance.

It is compulsory for the independent sections situated inside residential buildings but used as small business establishment, bureau and similar purposes but it is not compulsory for the commercial buildings. New construction cost of the building according to actual market price is going to paid at the time and location of the earthquake location (For more information see www.dask.gov.tr).


CEI

# DETERMINATION OF SEISMIC SAFETY OF EXISTING STRUCTURES

It must be taken into consideration that seismic safety of buildings has many steps. For this purpose, a chapter called" determination of seismic safety of existing structures and retrofitting of structures" is included Turkish Earthquake Code which is named "Specification for the Buildings to be Constructed in Seismic Zones, 2007". It has been become operative since March 2007. In new earthquake code, determination of seismic safety of existing structures and.

calculation steps are detailed. Especially after 1999 Kocaeli Earthquake the need for controlling of determination of seismic safety and retrofitting works has arranged has revealed. After an comprehensive study a new Chapter has been added to the Specification for the Buildings to be Constructed in Seismic Zones, in 2007 to regulate the seismic safety assessment of the existing reinforced concrete building and retrofit design of them.

The main steps of determining seismic safety are as follows:

- First of all, there must be taken advice of specialists of seismic safety who are the civil engineering departments of universities, chamber of civil engineering and certificated civil engineers by Ministry of Construction.
- The first step of determination of seismic safety is checking whether structure was constructed according to design project. After controlling of size and position of columns and beams which are the member of load carrying system on a plan, new design project is prepared.
- The materials used in existing structures must be tested whether they provide required quality by taking samples from rebars and concrete.
- Calculations are done in accordance with the Specification for the Buildings to be constructed in Seismic Zones, 2007.

The results are assessed according to Specification for the Buildings to be constructed in Seismic Zones, 2007 and come to a decision.

# FREQUENTLY ASKED QUESTIONS

**Does it mean that having so much of rebars in a structure is a sign of earthquake safe building?**

It is more important using appropriate amount of rebars in elements of load carrying system of reinforced concrete structures which are columns, beams, shear walls than using in huge amounts. Having great amount rebars may cause damage if they are not placed according to code.

**Do masonry buildings have less seismic safety than reinforced concrete structures?**

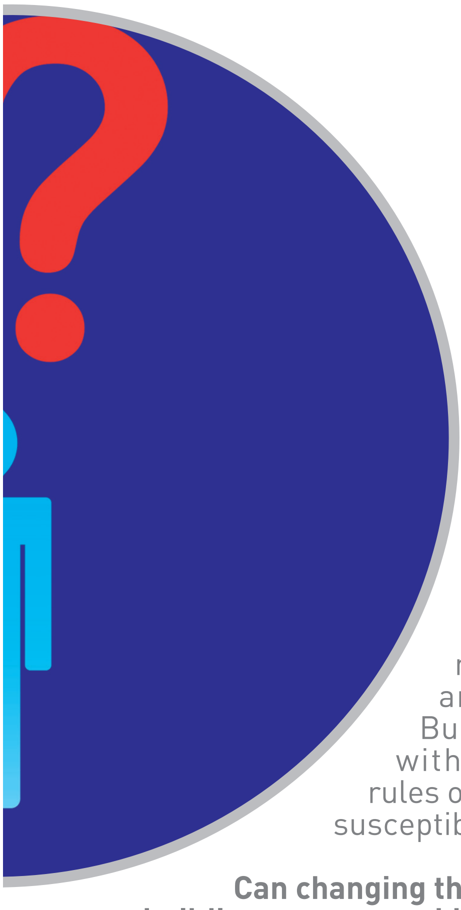
No buildings have more seismic safety than the other. All structures are earthquake safe if the code restrictions are conformed.

**Is it a good choice housing on a building which has a mat foundation?**

The important thing is having foundation size and type according to loads acting on building and to soil type. There is no any superiority between foundation types.

**I am sitting on building which is located on soft soil. Will my building have damage in an earthquake?**

Buildings with foundations designed according loads and soil properties have a low possibility of having damage in an earthquake.



**Do Multi-storey buildings have much possibility of having damage in an earthquake?**

There is no any relation between number of storey and seismic safety. Buildings constructed without applying the rules of codes have always susceptible to have damage.

**Can changing the usage purpose of building cause a problem?**

Using buildings with the exclusive of usage purpose can affect seismic safety badly changing both loads acting on buildings and anticipated earthquake behavior of building.

**Do extracting infill walls to have more space in a building make risk in terms of seismic safety?**

It must be avoided that changing the original shape of structures affects seismic safety of building.

**There are some misapplications that can adversely affect seismic safety of building. What can I do to bring out these effects?**

If a misapplication is detected, building must be investigated by a civil engineer.

# GLOSSARY

**Reinforced concrete:** a building material which are composed of concrete and reinforcement bar.

**Infill wall:** infill walls which are members of load carrying system of structures is used in reinforced concrete structures to separate rooms. It has effects on earthquake behavior of structures. It is build from hollow brick.

**Rebar:** it helps structures to carry load which are added into concrete.

**Epicenter:** it is the closest point to focus on earth. It is the plcade where the earthquake shaking is felt strongly.

**Stirrup:** it is the element which confine the longitudinal rebars to prevent concrete disintegrate. It is placed in concrete periodically.

**Fault:** it is the cracks zones between the plates, which constitutes earth's crust.

**Girder:** it is used to in carrying walls of masonry structures to integrate them. It is placed vertically and horizontally to prevent weakness due to the spaces of door and walls which are made of reinforced concrete.

**Pile foundation:** it is foundation type which is used under high storey structures located on soft soil to transfer loads to hard soil by piles.

**Short column:** it is a column in a storey of a reinforced concrete structure which behaves short column due to architectural and structural obligation.

**Beam:** it is rectangular shape of horizontally placed reinforced concrete member of a structure that binds vertical load carrying elements.

**Column:** it is vertical load carrying elements that have in similar sizes in two directions on plan.

**Corrosion:** it is rust on rebars due to humidity and water from outside the reinforced concrete elements.


**Cure:** it is maintenance to be applied on fresh concrete to reach its anticipated strength.

**Hypocenter:** it is the point where the earthquake happens in underground.

**Shear wall:** it is a vertical load carrying elements of reinforced concrete structure that have a ratio of seven in plan sizes.

**Mat foundation:** it is a foundation under high structures situated on soft soils that are applied under whole building with a thickness.

**Load Carrying element:** it is a structural element that carries vertical and horizontal loads acting on structures.

**Load Carrying system:** it is a structural system constitute from load carrying elements to carry vertical and horizontal loads acting on structures safely.

**Foundation:** it is a member of load carrying system which transfers the outer loads acting on buildings to the ground.

**Building audit firm:** it is an independent quality controlling firm established by the law 4708 that is responsible for the design and construction phase of structures.

**Masonry wall:** it is a carrying wall in masonry structures.

**Soft storey:** it is the storey where the continuity of walls is broken

**Load transferring system:** it is system to transmit the loads acting on building safely to the ground in short.

**Soil investigation:** it is experiments all done insituon or in laboratory to investigate bearing capacity and dynamic properties of the soil.

**Compulsory Earthquake Insurance:** it is a compulsory insurance which has published on 27.12.1999 with a Decree Law No.587 "Decree Law Relating to Compulsory Earthquake Insurance" that has given birth to Turkish Catastrophe Insurance Pool (TCIP). The owners of buildings in municipality district will be paid for the damage caused by an earthquake.

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## FIGURES

Figure 14, 15, 23a: Depreme Karşı Yapısal Bilinç, Boğaziçi Üniv., Kandilli Rasathanesi ve Deprem Araş. Ens., Afete Hazırlık Eğitim Projesi.

Figure 20: Dep. Y. Müh. Murat E. SELÇUK, Kişisel Arşiv 1999 Kocaeli Depremi, Adapazarı.

Figure 21: www.ce.washington.edu

Figure 44: Deprem Bölgelerinde Yapılacak Binalar Hakkında Yönetmelik, 2007.

Figure 45, 60, 63, 64: Depreme Karşı Yapısal Bilinç, Boğaziçi Üniv., Kandilli Rasathanesi ve Deprem Araş. Ens., Afete Hazırlık Eğitim Projesi.

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