*Dilek DİREN
** Dicle AYDIN
* Ms.D.Architect, The Turkish Republic, Bank of Agriculture, Directory of Region of Konya, KONYA
** Ms.D.Architect, Selcuk University, The Department of Architecture, Research Assistant, KONYA

TRADITIONAL HOUSES AND EARTHQUAKE

INTRODUCTION

Houses, being the surviving-living places; have been formed due to the conditions of a specific place and time and acquired a shape by having been developed under the economical conditions of a specific society and a specific user group. Also in our country, life styles, family sizes and member relationships in families began to change at first slower then quicker with the effect of Europe culture in 19th century, then changed quickly parallel to the social, cultural, economical and technological changes. And these changes are reflected to the houses which are living and surviving places.

Having been become a united whole with the technology brought by the time and the change in material and construction technique, the houses changed the silhouttes of the cities especially big cities after 1950s throughout the country. Especially in city centers, high land values and having differences in the structural development have formed economical press on the historical house regions. All of these have damaged the present historical heritage, present construction techniques and culture of society by constructing reinforced concrete structures on to the places of our traditional houses that had been formed from the accumulation of hundred years. The production of house with traditional construction system is still continuing in rural regions.

Our country is subjected to the destructive earthquakes because of its geographical location, geological and topographical structure. Most of the people in our country live in 1st and 2nd degree earthquake regions in respect to the location of settling and industry centers. As a result of crooked urbanization formed from rapid population increase and interior migrations; lands gained value, floor additions occured and the construction quality fairly decreased in the living centers. This is an employment order which doesn't consider good and bad and disregard the society completely. Instead of creating a good environment and producing houses of high quality to people, people turned to get more profit.

The observed things after earthquakes are that the houses having been built with traditional construction techniques had little damage and did not cause too much life loss. In that case the right thing should be to bring the ones brought by the time and our society's

cultural accumulations together and then to use the good ones and throw away the bad ones. Because of this, in this study; the construction techniques and material properties of the traditional houses were investigated and their positive and negative sides were tried to be determined.

TRADITIONAL HOUSES

The shape of the traditional Anatolian house formed as a result of a successfull synthesis of the properties caused from the Turkish culture of Central Anatolia with Anatolia's historical, geographical, climatic properties, construction material, technique and İslamic family understanding that the cause of these houses having many common properties with each other is this.

But, traditional houses show some differences related with the regions in which they take place. These differences are caused from the climatic effects and the present construction materials existing in the region. This does not affect the structure's shell and does not change the location thought which forms the self in the traditional house (1-2).

The traditional houses are the structures which are suitable for the human properties in the scale of street, neighbourhood, city and they are respectful to each other's privacy and do not cut the sunshine of each other and have different floor arrangements structurally. The houses are seperated from the street by a court. The service places like barn, hayloft and kitchen take place in the garden as a seperate structure. In some houses, these service places are located in the lower floors of the houses (Drawing 1).

Drawing 1 – The house of Konya Özkaymak (Kişnişçi) has been seperated from the street with a garden and the service places have been solved in the garden adjacent to the structure. In the structure there have been used adobe masonry work and lath construction techniques together (3).

Because of the reasons of Türk-İslam family life, the obligation of food production to be done by themselves and protection, the house's that floor is planned to be used inside the house. The walls are deaf or have little windows.

The basic property of the houses which generally have a symmetrical or near symmetrical plan scheme, is considering the room as the principal unit. The living floor of the house is generally the upper floor. In this floor, there exist the rooms and the hall which is common living place and to which the rooms are opened. Being contrary to the ground floor,

the upper floor has many windows (Drawing 2). The rooms are commonly in the quadrilateral form. In this floor, there were made projections which are called bays in order to create regular places and turn towards to the sun (Photo 1-2) (3).

Drawing 2 – The house of Konya Muharemoğlu has been built with its symmetric plan scheme as lath and adobe masonry work. The walls of the ground floor are made up of stone till the bottom of the window. (14)

TRADITIONAL HOUSES AND EARTHQUAKE

Earthquake; is the complicated elastic movements caused from earth movements occured as a result of discharging of the straining energy accumulated on the cracks named as fault inside the earth. It is the vibration action of the earth because of the energy spreading in waves (4).

In every year, there are occuring more than a hundred earthquakes which have the magnitude of more than V in the world and the monetary loss caused from these earthquakes is expressed with billion dollars. (V is a severe earthquake. When the magnitude of earthquake is equal and greater than V, then the life and asset losses begin.) This opens great injuries on the economies of the countries.

Photo 1 – The entrance facade of the house of Özkaymak (Kişnişçi) in Konya.(3)

Photo 2 – The east facade of the house of Konya Cimcimeler and the view of the cottage in the garden. The archs of the cottage have been built as lath.(3)

As it is known, Turkey is found on a very active earthquake zone (Map 1). There had been many earthquakes which had magnitudes of greater than V between the years B.C. 427 – 1999 (5). According to the latest earthquake map, 96% of the total area of Turkey is I., II., III. and IV. degree earthquake region. 98% of the total population live with the danger of earthquake of various degrees (6).

Map 1 – Earthquake zones in Turkey (15)

Especially Marmara Region earthquakes occured in the last years caused a lot of loss of lives and properties in our country. In the site studies, it was determined that the structural dama, property and life losses are more in the reinforced concrete structures which were built with today's technology in comparison with the traditional structures.

By the studies and the investigations carried out in these regions, there were determined that the structures haven't been designed and constructed suitable for the earthquake requirements that the examples to these are as follows; the concrete strengths of the structures that have collapsed or had great damage were less, there was formed soft floor in the buildings, short columns have been twisted because of the earthquake, because of the load-bearing system not fixed rightly to the structures' center of gravities did not fit or come nearer with the center of rigidity of the structures, the reinforcements in the concrete have corroded, the soils on which the structures have been constructed, haven't been researched well, there have been built more floors than the required, etc. (Having the size of 7.4 and magnitude of X this earthquake continued for 45 seconds.) (5)

Nowadays, modern engineering works hard to solve the earthquake problems of the structures on a large scale. But, the earthquake problems of the traditional houses and the rural houses which have been built using these construction techniques haven't been succeeded to be clear. In spite of this, it is possible to approach and bring a solution to the subject emprically with the observations and interpretations about the earthquake and also

scientifically with the experimental methods. On the other hand, although the problem is difficult there are some facilities that provide easiness in the solution. It is as follows: Such houses are produced with the same material and conctruction technique in all over the world (stone, adobe, wood, primitive construction technology). As a result of the earthquake experiences gained during many centuries in that region, the instinctive non-seismic construction techniques have been formed by the generations and transfered to each other. (Rural house : is the structure constructed by the person who lives in, without any engineering maintenance and using the rural material and technology.) The traditional houses are also included in this definition(7).

In order to solve the subject, the construction techniques and the material properties of these houses should be well studied. Moreover, these houses have been subjected to earthquakes in their construction dates and before the construction dates in their existing regions. It was seen in the latest earthquakes that these structures suffered damage. Also some of them had great damage. But the life losses were less and the houses were not destroyed completely that the people living in had got time to leave the structure and also some of them saved their assets too. Their ruins were put away easily and the people left under theruin could be rescued.

The thing that is wanted to be said here is not “leaving the construction techniques brought by the time or reinforced concrete, turning to the traditional ones, making our structures with these construction techniques and materials with the conditions of those old days”. Our structures should be constructed by taking lessons from these facts, determining the construction properties of these structures carefully and transfering all of these to our current life. For doing these the material and construction techniques of the traditional houses should be well investigated.

THE CONSTRUCTION TECHNIQUE AND THE MATERIAL PROPERTIES OF THE TRADITIONAL HOUSES

The construction materials used in the traditional houses were wood, stone and adobe. The traditional houses have been built by gathering these materials together with various combinations according to the region’s climatic conditions, regional easily obtainable conditions, geographical and topographical conditions. The structural material property of the region has obliged to build the houses with this material. Wood has been prefered because of its lightness and allowance to various details, when it was found.

Especially in Black Sea, Marmara, Thrace, Aegean and Mediterranean regions the wooden material has taken its place in the structural system as the load-bearing and place

restrictive. In the regions where the obtaining of wood was difficult, there has been used wood in the structural members of the traditional houses and the openings have been filled with stone and adobe. Or the structures have been completely built from adobe or stone as a masonry work. Again the doors, windows, floors and ceilings of these houses has been made from wood (1).

The traditional houses can be seperated into three groups according to their load-bearing systems. While the skeletal constructions have been formed from wood, the masonry work massive constructions have been formed from stone or adobe according to their load-bearing walls. And also there exist hybrid structures in which both construction techniques have been used together (Photo 3). In the traditional houses constructed as massive walled; the walls perform the functions of enclosing the using areas and carrying the horizontal and vertical loads affecting on the structure. They can be single-floor or duplex. The used material is stone or adobe.

Photo 3 – A structure built with stone till the bottom of the ground floor over which was built with wooden massive construction (1).

The walls in the basements of the traditional houses have been built from stone in everywhere. There are usually used stone walls in the ground of the traditional houses with or without basement. The building gets 50 cm. higher than the ground with these stone walls. This is because of the water or moisture coming from the ground not to affect the wooden or adobe materials used in the main floors. Because moisture damages the structural properties of both materials.

The stone walls; have low costs because of not needing quality in material and workmanship. But from the point of view of the structural property, it is the weakest wall type. The peripheral ties used between the walls increase the strength of the stone walls (8)

In the regions where the stone and wood can not be obtained easily and the climate is drought, especially in the region of Central Anatolia, the construction material is adobe (8). This material which is formed from the mixture of earth and straw is in the form of blocks (27 × 27 × 10 cm. or 14 × 27 × 10 cm.). The thickness of the wall is between 65 and 75 cm. These

blocks are connected to each other with mud mortar made from earth (9). The adobe is a material which should be plastered every year with mud plaster. (Photo 4)

Photo 4 – A settlement in Central Anatolia formed from adobe structures (1).

The earth sourced adobe; is affected from moisture and scatters. The strength of the adobe walls whose load-bearing capacities are generally less, can be increased with peripheral ties (8). One of the weakest properties of the adobe walls is becoming soft and losing its strength under heat.

At the roof, there are made dense cross-beams with the round sectioned poplar trees and earth is placed over them. A drawback of the adobe structures is that their roofs are earth roofs. The roof load is too much. Wood has been obliged to be used for the architecture members of window, door, roof, floor in the stone and adobe structures. The floors of these structures are also from wood.

Wood; is light but rather strong material. It is easily affected from weather conditions. Moisture and rain cause decays on wood. And also, insects and worms eat wood from inside and weaken it. By the time wood gets drier, and because of the wood which has nails, screws and notched crossings get dry and shrink, there are caused loosening and weakening of the joints. Also against fire risk, wood is the most inadvisable material in comparison with the other construction materials.

The wooden skeletal structures; are the structures which are formed from wooden posts, cross-bracings and from the infill materials of stone, adobe, barks that change according to the rural conditions. These infill materials are placed between the openings of these posts and cross-bracings. The wooden posts existing in the walls of these structures and the infill material carry the horizontal and vertical loads altogether. In some cases (for the duplex ones) the ground floor of the structure can be stone masonry work and the first floor can be wooden skeletal. The wooden skeletal constructions have two types of Nog and Lath constructions due to its construction technique (9).

The Nog; is the type in which there is formed a wall skeleton by placing the wooden posts vertically and diagonally before making the walls. Later the openings are filled with infill material which can be easily obtainable from the region (like stone or adobe). The usage

of mud mortar for infill is so widespread. Afterwards the two faces of the wall are plastered with mud. The roof are constructed by covering earth and clay roof tiles on a framework formed from posts (8).

The Lath; is a more developed construction type than the nog. There is formed a wall skeleton by placing the wooden posts orderly in the vertical, diagonal and horizontal directions. On the interior and exterior sides wide and smooth board pieces are fastened with nails. The opening between the two board faces is filled with mud or left empty. The exterior surfaces are plastered. The walls of the Lath structures are thinner than the walls of the nog structures, in this scale the heat insulation becomes less. The lath structures in which wood is morely used lighter than the other structures. Their roofs were put up regularly and covered with clay roof tiles on the framework (8-9).

THE BEHAVIOURS OF THE CONSTRUCTION TECHNOLOGY AND MATERIALS OF THE TRADITIONAL HOUSES AGAINST EARTHQUAKE

Being well-skilled in using the local construction materials caused self detailed solutions in the houses. These techniques have been formed as a result of various experiences and by being transfered from generation to generation until they reached today and developed .

The properties of the construction materials that are durable against earthquake are as follows.

1 – The structure should be light; because, the loads affecting on the structure in an earthquake, are proportional with the weight of the structure. Heavier the structure higher the load which affects the structure during any earthquake. If there are two structures one of which is lighter than the other and both of them are built with the same type of material, it will be waited that the lighter one will have less damage than the heavier one.

2 – The structure should be elastic; in other words the structure should be able to make displacement under a specific load. This property provides the structure to absorb more energy during the earthquake. If the energy affecting on the structure during the earthquake is equal to this energy area of the structure, the structure will have no damage.

3 – The structure should be ductile. The materials used in the construction should not break off under a specific load. To some extent the material should be able to make extension. The ductile material, in other words the material which makes large deformation, has more power of absorbing energy and it is a more durable material against earthquake (10).

Being a heavy material, stone is not elastic and ductile. The properties of stone change according to its type, formation, shape and mineral structure. These properties determine the

strength of stone against pressure. The brittle ones break down quickly and do not make large extensions before being broken off. They provide good heat isolation. The obtaining of stone is easy (11). Especially in the basement walls and foundations of the traditional houses, there are used hard stones which have high pressure strength, high resistance against frost and have not been affected from moisture.

There are made interlockings with the regularly cut stones in the junction of the two rubble stone walls which intersect each other vertically. This interlocking prevents the seperation of walls from each other during the earthquake. As shown in Figure 3, the most effective method is to place wooden peripheral ties with definite intervals along the wall. The ashlar stone walls have better structural properties compared to the rubble stone walls. Also in the ashlar stone walls there have been used wooden peripheral ties in order to provide contribution against earthquake. The masonry work walls having peripheral ties show more resistance against earthquake when compared with the walls without peripheral ties. Because of stone being a heavy material, the displacement property of the structure against earthquake has been increased a little.

The adobe, having less and insufficient resistance against earthquake is a material which does not have any elastic and ductile properties. Because of having low load-carrying capacity and pressure resistance, they are broken quickly and do not make extension before breaking off. They provide good heat isolation. Their obtaining is easy. Because of being an earth sourced material, water and moisture destroy its structural property. The strength of the adobe walls can be increased with the peripheral ties as seen in Figure 6. But softening and losing its strength when heated is one of the weakest sides of these structures. When destroyed completely, there can be rescued living body under its ruin which is easy to put away (10). But in adobe structures; not connecting the flat earth roof to the wall well and not projecting the logs which sit on the wall enough cause these to slide from the wall easily and fell down during the earthquake (9).

During the earthquake the masonry work massive constructions are not only subjected to horizontal loads parallel to the planes. Especially the walls are subjected to dynamic and horizontal loads to a great degree during the earthquake. In other words they are affected both from horizontal and vertical loads during the earthquake. This is also the cause of the damage formation. When there are applied horizontal loads to the walls of this type of structures in their own planes and parallel to the joints, there occur failure, horizontal shear and diagonal tension in the joints. There occur cracks because of the walls having low shear and tensile strengths (11).

The walls are supported with the walls that come vertical to them. For being resistant against the earthquake, the exterior wall's void ratio of these structures has great importance. There should be found sufficient infilled wall that can carry the horizontal loads applied to the structure. The materials stone and adobe are not durable against the shear and tensile forces and have large empty wall ratio, then this cause the structure to be destroyed during the earthquake. But placing wooden reinforcements inside the walls in the horizontal and vertical directions prevents the structural cracks formed during the earthquake to get larger and prevents the structure to be destroyed when the magnitude of the earthquake is not high. The loads affecting on the structure in the horizontal and vertical axes cause damages in the intersections of the walls.

The masonry work structures that have less floors and less wall void ratios, are more durable than the ones having more floors and more wall void ratios. The structures may have damage in the earthquake but they don't cause any life losses. Using two different construction materials having different elastic properties, creates unrigidity in the structure. This causes negative situations during the earthquake (11).

In the earthquakes, the wooden structures; are subjected to smaller forces than the structures made up of stone, brick, masonry work and reinforced concrete. They can oscillate easily without breaking off under the vibrations which the structure is subjected to in the earthquake (10).

The main reasons of earthquake damages occur in the skeletal wooden structures are; making the joints of load-bearing woods insufficient or weakening of joints by the time (because of the dried wood, the loosening of the joints), having little infilled wall parts by leaving large holes on the walls for windows and doors that can carry the horizontal and the vertical loads. In this situation, having less number of crossings and posts which will be insufficient, will become effective on the damage. In these structures, the fire risk in an earthquake can occur whether the wooden skeletal parts of the structure are not connected well to the foundations or to the masonry work ground floor walls and they fall over.

In the wooden skeletal structures; the posts are very effective for carrying vertical loads but so weak against horizontal loads. There are placed crossings on the walls to provide resistance against the horizontal loads (10). Because of the wall being light and the wooden joints being strong, the lath structures show good resistance against the earthquake .

In terms of earthquake, another advantage of this light wood is to have more possibility of remaining alive under a destroyed wooden structure. In other words, although the wooden skeletal structures have large damages in the earthquake, the masonry work

massive structures cause less life losses (Figure 1). And its ruin is easy to put away (4). Briefly, wood is more superior than stone and adobe in terms of durability against earthquake (Figure 2).

Figure-1

The diagonal members which will be used in the structures provide to exhaust energy by resisting against the loads formed from the earthquake and have little torsional damage. There have been used these diagonal members in the load-bearing systems of the traditional houses.

Figure-2.

But the crossings should have the same horizontal and vertical angles in order to have the same benefit in load carrying both in the horizontal and vertical directions. In other words, they should be placed with the angle of 45° (10).

The floors of the traditional houses are made up of wood. The wooden floors are not as rigid as the reinforced concrete plates, so then the wooden floored structures have more damage (9). The floors; are formed by nailing the wooden ceiling beams that are placed on the walls from up and down with the covering planks. The covering planks are generally nailed to the beams with the angle of 90°. When this angle is 45°, the floors have less damage from the earthquake .

Having nearly regular plan and being symmetric or nearly symmetric according to the main axes, the traditional houses are stable. If there are not made any product faults, the system is settled well, the foundation is built well and the horizontal and vertical loads are transfered well, there will not occur any resonance during the earthquake because the own weight of the structure is not more than the modern structures. The structure is not destroyed (Photo 5).

Photo 5 – This traditional house suffered damage in August 17th 2000 earthquake in Sakarya but did not collapsed (From: Mustafa İncesakal-S.U.Architectural Department).

CONCLUSION

Our period has changed the life style, social culture, living environments and living places (the most important one) which decreases the individual importance of the person without paying attention to the local limitations and potentials with the manner that accepts the superiority of technology and its bringings. Having started firstly in our cities with today's tecnology which gives opportunity mostly to survive in and to build high structures, the action of apartment building has taken the smaller living places under its influence quickly.

All the architectural structures are built for servicing to their users' needs and preferences by using construction techniques and materials. It provides opportunity to the formation of new construction techniques in material science and construction technique. Our traditional architecture has been formed by solving the technology and demands with rationalistic approaches. Nowadays there are lived contradictions formed from the lack of harmony of modern architecture, technologies or ideologies with the local conditions.

For the houses that will be built new, the traditional houses can be the key of many solutions. Moreover, taking the traditional houses as an example, the structural members can be produced with sensitivity as an industrial production with today's technology, or there can be produced materials that will be replaced with these and the structure can be provided to become industrialized and the structure's production quality can be increased and the construction cost can be decreased.

Today's structures are multi-storied; then the construction system is more expensive, the construction cost is higher because all the floors are carried by the lower floors and so providing strength against the earthquake in the high structures is more expensive than the precautions taken to provide strength in the little-storied structures. For this reason, the houses that will be built in the earthquake zones should be little-storied as in the traditional houses.

In the investigations made on the earthquake zones, there were observed architectural and statical irregularities in most of the damaged buildings. This situation causes torsions in the buildings because of the earthquake and the center of gravity takes place in a very different point instead of fitting with the center of rigidity. For this reason, the construction

plans should be symmetrical or near symmetrical and the load-bearing system should be well solved.

The traditional houses are light structures which have small, balanced, quadrilateral planned mass. This is positive for the structure during the earthquake. For these reasons, in the horizontal plane, the structures that have plan schemes as T, L, U and heavy mass, should be seperated into quadrilaterally planned pieces in a sufficient amount and each piece should be built seperately. This will prevent the structure against torsion during the earthquake.

The resistance of the structures against the loads coming from the ground because of the earthquake, is also due to the properties of the used material. For this reason, today's structures should also be constructed with light and ductile materials as in the traditional houses and the structures should be able to make oscillation during the earthquake. For example, the wooden material used in the traditional houses is prefered today in the construction sector, because it is ecological, light and durable against earthquake and provides good air-conditioning in the structure (In Canada, there are made wooden construction production (13).

Because of the construction technique used in the traditional house, it is not allowed to make any changes for gaining place in the load-bearing system or creating wide places. Also in today's structures, there should not be played with the load-bearing system and should not be allowed to the formation of soft floor.

The construction technique of the traditional houses; has an upper structure formed from the construction materials that are placed on the permanent walls connected to the ground and having light and modular property. This construction technique and the materials provide the opportunity of care, repair, change-development of the needs that change from generation to generation with the elasticity provided by the construction technology, they also provide superiority to these houses in terms of economy. Also in today's houses, developing and applying (especially in earthquake zones) construction techniques that will provide these properties will be useful in terms of economy.

REFERENCES:

1-SÖZEN.M.- ERUZUN.C.1992, "*Anadolu' da Ev ve İnsan",* Emlak Bankası Yayını

2-ÜNÜGÜR.M.-ÜNÜGÜR.H.T.1992,"*Gelenekten Geleceğe Evimiz Proje Yarışması Raporu",* T.C. Kültür Bakanlığı Genel Müdürlüğü,s.150-153

3-TOZOĞLU DİREN. D.1995, "*Konya'da Mimari Özelliği Olan Bazı Geleneksel Evlere Yeni Fonksiyon Verilmesi Üzerine Bir Deneme*", Yük. Lisans Tezi, Konya

4-ANONİM; 1997, "*Deprem Dergisi",* Türkiye Deprem Vakfı, Şubat

5-ANONİM,2000, "*17 Ağustos 1999 İzmit Körfezi Deprem Raporu",* T.C. Bayındırlık ve İskan Bakanlığı Afet İşleri Genel Müdürlüğü Deprem Dairesi Başkanlığı, Ocak, Ankara

6-ÖZMEN. B.,NURLU.M.,GÜLER.H.,1997, "*Coğrafi Bilgi Sistemleri İle Deprem Bölgelerinin İncelenmesi"*, T.C. Bayındırlık ve İskan Bakanlığı Afet İşleri Genel Müdürlüğü,Ağustos,Ankara

7-ARIOĞLU E.- ANADOL K. 1974*, "Türkiye 'de Kırsal Konutların son Yıllardaki Tahripkar depremlere Mukabelesi*", Deprem Araştırma Enstitüsü bülteni. y.2 , s.5, Ankara

8- ANONİM, 1990, *"Kırsal Yapılarda Deprem hasarlarının Tayini",* T.C. Bayındırlık ve İskan Bakanlığı Afet İşleri genel Müdürlüğü, Mart, Ankara

9-ANONİM, 1978, *"Türkiye'deki Kırsal Konutların Depremler Karşısındaki Gözlenen Davranışları*", T.C. İmar ve İskan Bakanlığı Deprem Araştırma Enstitüsü Başkanlığı , Mayıs Ankara

10-BAYÜLKE. N., 1976, "*Depreme Dayanıklı Yapılar"*, Ders notları, İ T.C. Bayındırlık ve İskan Bakanlığı Afet İşleri genel Müdürlüğü,eğitim dairesi, Ankara.

11- BAYÜLKE. N. 1980, "*Yığma Yapılar",* T.C. İmar ve İskan Bakanlığı, Deprem Araştırma Enstitüsü Başkanlığı, Ankara

12- KALKAN. İ., BAYÜLKE. N., *"Türkiye'de Deprem Zararlarını Azaltma Çalışmaları Raporu"*

13- ANONİM, 2000, "*Hürriyet Gazetesi",* 20.08.2000-08-25

14- SÖZEN, M-DÜLGERLER, O.N. 1979 *"Konya Evlerinden Örnekler"* ODTU Mimarlık Dergisi Sayı:1 cilt:5

15-http:/www.deprem.gov.tr