Wooden Architecture and Earthquakes in Turkey: A Reconnaissance Report and Commentary on the performance of wooden structures in the Turkish earthquakes of 17 August and 12 November 1999[1]

Stephen Tobriner
Professor of Architectural History
University of California, Berkeley 94720
email: tobriner@uclink4.berkeley.edu
tel: (510)642-4098; (510)642-4942

The widespread failure of reinforced concrete buildings in the İzmit (Kocaeli) earthquake of 17 August 1999 and Düzce earthquake of 12 November 1999[2] not only forced Turkish architects and engineers to reassess reinforced concrete construction, but pushed a few of them to reconsider a discarded technology, traditional Turkish wood construction.[3] This paper aims to establish both a cultural and an engineering context in which to position historic wooden architecture in Turkey. It seeks to answer two questions: First, is there any evidence to suggest that these historic wooden structures were designed to resist earthquakes? We must turn to the historical record, look for coeval similarities around the world, and evaluate the surviving wooden buildings to propose an answer. Second, how well did wooden buildings perform in the recent Turkish earthquakes of 17 August and 12 November 1999? By evaluating the performance of Turkish wooden houses we can observe their strengths and weaknesses which will determine whether they are inherently safe in earthquakes. This paper is meant to open the scholarly dialogue concerning Turkish wooden architecture and earthquakes. I cannot present a complete study of this vast subject here but it is my hope that this paper will provoke further debate and in so doing encourage future research.

The history of antiseismic[4] wood construction in Turkey can only be discussed speculatively because so little has yet been published on the subject.[5] Did the people who lived in Turkish wooden houses during the 17th through 19th centuries believe they were safe in earthquakes? Was it the intention of the builders who constructed Turkish wooden houses to make them seismically resistant? By the early 17th century timber frame construction for non-monumental buildings became popular in Istanbul replacing or being combined with earlier mud brick construction[6] While monumental buildings like mosques, külliyes, and palaces were constructed of stone and brick, vernacular houses were built using a stout wood frame, as Pietro della Valle describes circa 1614: "They first build a timber frame as in the ships and cover it by boards from the outside. The filling is of mud-brick or simple adobe."[7] Two devastating earthquakes shook Istanbul in the 16th century followed by two in the 17th century and three in the 18th century.[8] Perhaps one of the reasons wood frame construction became nearly universal in Istanbul from the 17th to the 19th centuries was its seismic resistance. But as safe as it may have been in earthquakes, wood construction was deadly in fires. Huge fires swept the city in the early 19th century causing authorities to bane further wood construction unless protected by brick fire breaks.[9] Further, the traditional single family wooden dwelling was increasingly regarded as a cultural liability as the Ottoman empire turned to western European urban prototypes like Haussmann's Paris for inspiration.[10] By the late 19th century multiunit brick apartment buildings were replacing traditional wooden houses. At the beginning of the 20th century reinforced concrete was introduced to İstanbul.[11] With each change in technology buildings grew in size. When reinforced concrete replaced wood as both the high style and vernacular architecture of Istanbul the advantage of wood construction in earthquakes was forgotten.

It is disappointing that so few official reports or directives have been studied in relation to seismic safety. Written documents describing Turkish wooden houses in earthquakes are rare but the few that survive provide tantalizing clues. One document, a two page description of earthquake recovery, was mistakenly published by Zarif Ongun as a description of the 1509 Istanbul earthquake but convincingly attributed by Caroline Finkel to the Istanbul earthquake of 1766.[12] During the earthquake, the Topkapı Palace was slightly damaged. The unknown writer tells us that wooden buildings were constructed for the safety of the Sultan and his family in the Topkapı Palace gardens or perhaps at Edirne. He also writes that the government imported huge quantities of timber and nails. In another document published by Ambraseys and Finkel, Brother Tarillon reports that after the İzmir (Symrna) earthquake of 10 July 1688 masonry construction was used only in foundations and the lower parts of walls. The upper stories of buildings were constructed of timber frames with brick infill, "a technique that proved resistant in the earthquakes that followed. "[13] This same technique was used in Lima after the 1746 earthquake and in Lisbon after the 1755 earthquake.[14] Masonry was restricted to the ground floor, and lighter, more flexible wood construction was used above. In Lima the lighter upper stories were constructed by using the *quincha*, a wooden framework with waddle and daub, while in Lisbon military engineers invented an x-braced internal wooden frame called the *gaiola* to support the exterior masonry walls above the ground floor. Pietro della Valle's 17th century description of the construction of the Turkish house quoted by Kuban suggests that it too was constructed to be seismically resistant because it was a wooden skeleton. Della Valle writes "They first build a timber frame as in the ships and cover it by boards from the outside." The comparison to ships is telling. Several centuries later and half way around the world in San Francisco an advertisement for a seismically resistant wooden-frame hotel in 1870 describes it as having been built like a ship.[15] In the aftermath of the Istanbul earthquake of 1894 both experts and ordinary citizens were impressed by how well wooden buildings performed.[16] The Director of the Athens Observatory called to study the earthquake, concluded that timber structures outperformed masonry buildings even if they were old and poorly built. It was because Istanbul was a timber city, he wrote, that the damage was not more severe. Citizens from one district of the city petitioned to rebuild in wood rather than brick because they believed wood construction was safer in earthquakes.[17] The clues provided by these few written documents can be corroborated by the Turkish houses themselves.

Turkish houses have features which unite them with antiseismic construction elsewhere. The most obvious is that they are made of wood. The property of wood to be flexible without breaking and to return after bending to its former shape makes it an ideal construction material in earthquake country. If beams and columns are sufficiently strong and flexible, braced and tied together to work as units, wooden walls can resist the lateral forces induced by earthquakes. Although the spaces between the timber frame may be filled with adobe, brick or simply left vacant, the wooden skeleton of the Turkish house can stand on its own as a self-supporting system. The timbers are simply nailed together but the framework is stabilized by the use of diagonal braces.

According to Dogan Kuban, the timber frame in Turkish houses resists earthquakes well because it is tied together in boxes and panels:

> *The main structural system in the Hayat houses was a timber skeleton used essentially over the masonry walls of the ground floor. This was neither a horizontal beam system nor a modern skeleton system. The connection between the horizontal and the vertical elements did not allow for continuity as in a modern structural skeleton. The continuity was not through the elements, thus linear, but it was like a box system where all the elements were integrated for the stability of the system. The primary and secondary uprights between the floors, horizontal elements, floor beams and diagonals, constituted panels and boxes. This system of continuous panels and boxes responds well under the stress of earthquakes.*[18]

The panel system Kuban describes can only be expected to function in an earthquake if it meets several criteria. First, the wood members must be sufficiently strong and ductile to resist and dissipate forces acting on the plane of a wall. They have to be strong enough to restrain and hold the skeleton and infill when pushed sideways. For example, the framework of the derelict building which Kuban labels Apolyont Köyü in Bursa (fig. 1) must be sound enough to bend back and forth and carry its load without splitting. Second, the connections between the members must be strong enough to hold together without loosening or worse yet completely failing. It is extremely unlikely that a rectangular upright panel, like the second to the right bay with the blocked in window in the Bursa house, could ever effectively resist lateral movements. It would simply deform and collapse. To resist lateral movement the frame must have diagonal or x bracing. This building in Bursa has x bracing on the ground floor and four kinds of diagonal bracing on the first floor: the vertical diagonal at the corner a little higher than half the bay, the horizontal diagonal on which the corner brace rests which reaches across the corner bay,
the smaller diagonals above the doorway and below the blocked up windows, and the diagonals above the doorway. We might also add the useless diagonals in the blocked up windows. How effectively these diagonals assist the vertical and horizontal members to resist lateral forces will decide whether the panels will function in an earthquake. The voids and solids within the panels, and the continuity between panel and panel, floor and floor, are crucial in the performance of the building as a whole. For example, the framing of the Hasan Aga house in Mudanya lacks diagonals on the upper floors and the diagonals

on the ground floor seem undersized. The builders are asking too much of the slender vertical timbers which support the upper two stories.

For the panels to work successfully as an antiseismic construction system they must be designed correctly, the more diagonal bracing the better. There is also an art to placing and designing diagonal bracing. The wider the base of the triangle in relation to its height the stronger it is. The diagonal should be connected to the vertical member as close to the joint with the horizontal member of the panel as possible. X braces are in general stronger than diagonal bracing alone. For all of these reasons the bottom floor of the house in Bursa has a far stronger frame than the upper floor.

Aesthetics and function have prejudiced the seismic stability of the Turkish house by limiting the locations of diagonals in the wall panel. Since corners are the most vulnerable to damage in lateral movement, builders have positioned the diagonals there. Even with changes in construction over the years these diagonals have been minimized to provide the maximum window area. This diminution of diagonal bracing can be seen in two diagrams Günay publishes illustrating versions of timber frame construction, the typical framing of the "old days" and "more recent date" (figs. 2 and 3). The controlling feature which will stabilize the facade or contribute to its failure in both cases is the diagonal at the corners. The problem with assessing the seismic vulnerability of these structures is that the diagonal bracing is inconsistent. It is not applied uniformly, nor is it the most prominent feature of these buildings.

Although we might argue about its effectiveness in resisting earthquakes the Turkish building system can be placed in the family of antiseismic wooden structures developing in the 18th and 19th centuries.[19] In Portugal the *gaiola*, mentioned earlier, utilized a wood frame to reinforce masonry buildings.[20] The system comprised a wooden framework of multiple x braces embedded in the cross walls of the interior of the buildings which stabilized an exterior rectilinear wooden skeleton attached to the masonry walls. Masonry protected the exterior from fire while the wood compensated for the brittle masonry. After the Calabria earthquake of 1783 another system, the *casa baraccata*, was invented. Instead of x braces on the interior walls as in the *gaiola*, braces were now positioned on the exterior perimeter walls.[21]

Architectural theorists of the 18th century were convinced of the efficacy of using wooden construction in earthquake-prone areas. Wood construction technology was revolutionized in the early 19th century in the United States of America by the invention of balloon frame construction.[22] In this system of machine cut 2 x 4 or 2 x 6 inch vertical studs placed at 16 inch. intervals nailed to horizontal members with wire-cut nails replaced heavy timber members secured by mortise and tenon joinery or spikes. Balloon frame construction was commonly considered to be seismically resistant in earthquake-prone 19th century San Francisco.[23] In general wood buildings were only wrecked in earthquakes when their brick chimneys collapsed, when they fell off their foundations, or when basement half-stories constructed with unbaced "cripple" walls, collapsed.[24]

Although Turkish houses do share traits with seismically resistant wooden buildings the question is still open as to the intent of their builders. The balloon frame was the simplest, cheapest, and fastest method of building in San Francisco. Its seismic performance was secondary. Such may have been the case in Istanbul. Reha Günay, in his *Tradition of the Turkish House and Safranbolu Houses*, concludes its simple nailed connections are indications of its ephemeral nature.

> *The broad-sectioned timber elements and carefully designed details seen in German, British or Japanese communities do not exist in the Turkish house. It is not just a coincidence that the same simple construction details can be traced in America, which throughout their history…people have been on the move towards the west. This construction method also facilitated the reconstruction, within a short time when whole quarters were destroyed instantenously [sic] by fire. The way in which people view life also plays a role in the selection of timber frame construction: Human life is temporary; it is only natural that houses are also built to last for a temporary period.* [25]

Further, it is important to remember that braced timber frames were popular in areas where earthquakes rarely struck like England, France and Germany.[26] When the timber frame is intentionally left uncovered on the facades of structures they are it is called half-timbered. Treatises on the aesthetics and construction of half-timbered building like Pierre Le Muet's *Maniere de bastir pour touttes sortes de personnes* (Paris, 1623) were not uncommon. In post-medieval England half timber originally buried in plaster was uncovered for aesthetic reasons.[27] Fake half timbering became popular in 19th century England and can even been seen copied in plastic in buildings in the United States today.

Although we cannot positively answer the question of whether their builders and owners intended Turkish wooden houses to be safe in earthquakes, we can evaluate the seismic performance of remaining buildings. Are surviving Turkish wooden houses safe in earthquakes? We can propose an answer to this question by examining individual buildings still surviving today. One of the greatest concentrations of 19th century Turkish wooden houses is in Safranbolu, a city designated as a UNESCO world heritage site because of its inventory of more than 800 houses. Safranbolu is in the Black Sea region of Turkey, north-east of Istanbul and by road about 150 kilometers from Düzce. Safranbolu suffered no damage from the two earthquakes in 1999. While it has been shaken in previous earthquakes which have affected the northern Anatolian seismic zone, according to Günay it has suffered no "serious harm".[28]

What, in general, can be said about the seismic safety of the buildings in Safranbolu? Of course, they incorporate the elements of the braced frame discussed above, which is an advantage, but each of the buildings has a its own strengths and weaknesses. A few general comments might help to focus attention on their shared problems. We might best examine them by analyzing their plans and elevations in relation to the concept of building configuration.[29] In general the more regular the configuration of a structure, the better. For example, a symmetrical, square building more evenly distributes forces and than an irregular L-shaped building. When irregularities occur they can create torsion and stress accumulation. Obviously, many irregular buildings are constructed in earthquake country, but when they are engineers must carefully calculate how these irregularities affect their performance. Regular configurations have several characteristics which optimize their performance: low height to base ratio, equal floor heights, symmetrical plan, uniform section and elevations, maximum torsional resistance, balanced resistance, short spans and redundancies, and direct load paths.

A few examples illustrate the variations in configuration at Sanfranbou. The sehir house of Arap Hacilar has an excellent configuration in plan whereas the Saraçlar sehir house (fig. 4) does not because it incorporates a *hayat*, or open porch on one side. This hallmark of the Turkish house presents a hazard in earthquake country because it is more flexible with no infill walls and less diagonal braces than the other perimeter walls. The tendency to twist under would be increased by the thick masonry wall across from the *hayat*. Further, the *hayat* in Saraçlar sehir house creates a void disrupting vertical continuity because it is two stories high and supports a *eyvan* (hall) on the third story. The walls of the Saraçlar sehir house present another vertical discontinuity. The middle floor is cantilevered over the ground floor. These cantilevers create a more complicated load path has the walls might rock back and forth in plane (in the direction of the wall) or out of plane (at right angles to the wall). The cantilever projections would tend to "wag" back and forth in an earthquake, stressing their connections to the main wall. These connections, called reentrant angles, might be stressed to the point of collapse.

Another important consideration is how the elements resisting sideways movement, or shear (a force which acts by attempting to cause planes of an object to slide over one another) are arrayed within the building. This is particularly hard to judge because the construction of bracing in the interior walls, and sometimes the exterior as well, is impossible to know. For example, the sehir house of Arap Hacılar would be more resistant to lateral forces than the Kaymakamlar sehir house with more voids and less interior and exterior walls.

The masonry ground floors of the houses of Safranbolu present two problems. Some ground floors are exceptionally high because houses are sited on steep slopes which means that the structure has a high height to base ratio. This creates an inherent instability in the structure as a whole as it increases the probability of rocking. But even more difficult to judge and potentially more dangerous is the masonry construction of the ground floor. In the United States the construction of the masonry ground floor would be called "unreinforced masonry." Under California law older brick buildings of this type of construction must be reinforced and the usual method is with concrete or steel. Engineers in the United States would consider the masonry walls of Safranbolu extremely hazardous in a strong earthquake.[30]

It is also important to ascertain how the forces are counteracted from story to story. Are the floor planes strong and stiff enough to act as diaphragms distributing the load to the walls? Are the connections between the individual members strong enough to hold the building together as it moves? The heavy tile roofs and stone infill in the timber frame create enormous weight and increased mass. Are the wooden connections strong enough to resist it? Turgut Cansever, the most famous living Turkish architect, is convinced the nailing system can resist seismic forces. He has seen extra-long nails and drew a sketch of them for me.[31] He also has seen the masonry foundations in buildings he retrofitted perform well in earthquakes.

A survey of performance of traditional wooden Turkish houses in the İzmit (Kocaeli) earthquake of 17 August and Düzce earthquake of 12 November, 1999 further helps to illustrate their strengths and weaknesses in earthquakes. The buildings shaken were not as old nor as beautiful as those at Safranbolu, but they were of the same timber-frame family.[32] The brief survey which follows includes Kaynaslı, Düzce, Ulaslı and Degirmendere

This small village of Kaynaslı north of Düzce was the epicenter of the so-called Düzce earthquake of 12 November, 1999. It is an agricultural village in a mountain valley bisected by the main east-west highway between İzmit and Bolu. The downtown area is located on a stream which runs south to east less than a city block south of the highway. The town follows the banks of the stream up a small valley rising south to the mountains. Although damage was considerable on both sides of the highway, the most spectacular damage was concentrated along the stream banks to the south. Here the reinforced concrete buildings of four to five stories failed at the ground floor causing many to settle one story.

Because Kaynaslı is a poor farming village it retained many wooden buildings in its housing stock and a dozen of these ascended the picturesque stream south up a hillside. Because they were on alluvial soil the shaking must have been intense. However they seemed to be excellent candidates for surviving an earthquake of considerable magnitude. These wooden buildings were very similar in design. They were one or two stories structures with square or rectangular ground plans, hip roofs and a moderate ratio of apertures to walls of 1.5 to 3. They were far smaller than the houses in Safranbolu and in every way more modest. They had none of irregular or discontinuous features (like cantilevered upper stories or *hayat*s) that characterized older Turkish wooden houses. These were regular blocks, probably with westernized floor plans, some so modern-looking that they appeared to be reinforced concrete apartment blocks. Their states of repair varied from excellent to extremely poor. All were of frame construction with heavy timber members and at least two diagonal timbers on each side, one was sheathed in wood. Some had an x brace or two on each side (fig. 5). In addition the interior walls were braced with diagonals. The infill was mostly brick sometimes stone and mud often artfully arranged in the wooden frame. Their responses varied but in general were no better than the reinforced concrete buildings. Most two story buildings lost their ground floors, some lost the diagonals or x braced shear panels while others slipped off their foundations. In at least three cases reinforced concrete structures hit or pounded against the timber frame buildings collapsing them. There were some notable successes: In one case a concrete building lost its first story sending heavy debris into a derelict timber frame house which in turn collapsed against another timber frame house shoving the second story sideways. Although the last building lost plaster it remained standing. Where the buildings were well built, one story, and had foundations that did not fail, they had a chance. The patterns of damage (broken plaster, lost panels) clearly show the diagonal panels taking the lateral load (fig. 6). Sometimes, even in failure they dissipated enough energy to save the rest of the wall.

Düzce was still recovering from the August earthquake when it was struck by the November 12 temblor. Downtown, a score of concrete buildings pancaked in the November 12 earthquake. In the central district whole blocks were badly damaged, others evacuated, and still others already demolished. Strikingly, next to several collapsed reinforced concrete buildings stood poorly maintained wooden buildings still intact.

The wooden buildings in Düzce included a type which can also be seen along the road to Kaynasli. These were square or rectangular apartment buildings of two stories with multiple entrances invariably painted green (fig. 7). There are hundreds on the outskirts of the Düzce, perhaps built as some form of public housing dating from the period of the 1920s and 1930s when, in order to contain foreign debt, the Union and the Progress Committee under the government of Atatürk encouraged a renewal of native building techniques and materials.[33] These buildings are quite different from the houses of Safranbolu in plan and elevation. As in Kaynaslı, these buildings are quite simple and unassuming. But note that their windows are placed well in from the corners and at wide intervals, making it possible to load the walls with x braces and diagonals which helps to make these buildings much more likely to resist earthquakes than the historic structures at Safranbolu. Several of these buildings survived in the downtown section of town near the river, sitting damaged but still standing among the ruins of collapsed reinforced concrete apartment buildings. Concrete buildings on three sides of the building illustrated in fig. 8 collapsed. Its neighbor (fig. 7) also survived, with its broken plaster finish exposing where the braced frame took the forces. Another strange contrast could be seen just next to the river where many reinforced concrete buildings pancaked. In back of the ruins of a pancaked reinforced concrete apartment building stands intact an elaborate but today derelict wood frame building (fig. 9).

Ulaslı is a small village near the sea about 15 kilometers west of Gölcük where major losses had occurred in the first earthquake. It is a village of low-rise reinforced concrete buildings and several dozen timber framed buildings on flat, well drained countryside. The ground-shaking here was not nearly as severe as in Kaynaslı judging from the damage. The ground-floor columns of the reinforced concrete buildings are cracked but structures still remain standing. But the citizens of the town insist that the timber framed buildings saved their lives. The little town is a treasure-trove of timber buildings.

Two structures, both with concrete additions, illustrate the pre-collapse damage patterns of timber framed buildings. The first is a two story rectangular building, wood framed with brick infill in a herringbone pattern in the front, probably brick and reinforced concrete in the rear. Cantilevered over the doorway is a timbered porch corresponding to the *eyvan* or hall. One enters the ground floor (perhaps a version of the *hayat*) and finds steps and a raised platform to the left. The center of the floor-joists is supported by a rough-hewn beam in turn supported by a single post with braces. On the right against the outside wall is the kitchen. The working of the diagonals in the earthquake dislodged the plaster as the house oscillated. A similar pattern can be seen in the back bedroom on the left hand side. In the front bedroom the vertical timbers on the exterior wall began to rotate. In the second, slightly larger house (fig. 10), the entire second story front facade with its wooden porch, is cantilevered over the ground floor as in older traditional buildings in Safranbolu and İstanbul. Diagonal bracing appears at the corners and in the center side elevation of the building. The ground plan and structure resemble the first house. Here the main cracking seems to be along the front facade and rear of the building with diagonal cracks at corners, probably where diagonal timbers are located. While some plaster fell and the buildings obviously moved they are not collapse hazards.

The downtown of Degirmendere, a seaside city not far from İzmit, was badly damaged in the August earthquake. Like Düzce, wooden buildings stood alone in areas where they had been surrounded by failed concrete buildings, now abandoned or demolished. In one downtown area a collection of buildings survives, some obviously lower class, others more sumptuous, two stories tall with central cantilevered porches probably corresponding to *eyvan*s under gable roofs. The latter probably date from the art nouveau period of the late 19th century. They appear undamaged from the earthquakes, but a group of reinforced concrete buildings beside them also fared well enough to be re-inhabited. In Degirmendere the wood frame is infilled with wattle and daub, making it far lighter than the brick and rubble infill walls seen in other locations.

The conclusion of this brief survey is that Turkish timber frame construction can be designed to be seismically resistant. In general this ancient system did as well as reinforced concrete structures nearby and sometimes markedly better. Granted there was a difference in scale which may have accounted for more failures in concrete. But nevertheless the performance of the wood frame houses was impressive. Unfortunately I did not have a team of investigators at my disposal with maps of the affected areas to make complete surveys. In an article published in 1989, M. Hasan Boduroğlu surveyed damage caused by sixty earthquakes between 1925 and 1984 to rural buildings in Turkey. Eighteen percent of rural buildings at that time were timber framed. He felt that timber framed buildings with hollow walls (*Bağdadi*) outperformed infilled timber frames (*Hımış*) and both were substantially safer than adobe or rubble stone masonry structures. He observes "The traditional construction techniques used in timber frame buildings have been very successful. In contrast to stone masonry buildings, they my adequately resist …earthquake forces."[34] But only by studying each building extremely thoroughly, calculating ground motion, and then finally modeling it using infinite element analysis in computer programs like SAP2000 or a pushover analysis will we be able to be sure of our judgments.[35]

Could wooden buildings again be built in Turkey? The answer must be that wooden buildings could again become popular as an alternative to reinforced concrete. Would they be safer than reinforced concrete buildings? They would certainly be safer than a vast majority of present-day concrete buildings in the Istanbul metropolitan area. But reinforced concrete can be designed to be seismically resistant as well. Wood in itself does not guarantee safety. Antiseismic design makes a structure safe. The use of wood as the dominant structural material raises many questions. Can it be used effectively in relation to the tremendous growth of the city? Because wooden structures will be smaller than standard reinforced concrete buildings, will they exacerbate urban sprawl? Will the use of wood degrade the remaining forest cover in Turkey and create a host of environmental problems? While these questions must be answered before large scale operations are undertaken, for the present it is possible to endorse correctly built wooden structures as a viable, intelligent option.

---

[1] This paper is an abbreviated version of a report for the United Nations Centre for Regional Development, Disaster Management Planning, Hyogo Office(IHD Centre Building, 4th Floor, 1-5-1 Wakihama-kaigan-dori, Chuo-ku, Kobe 651-0073 Japan). It was published by that office under the title "Wooden Architecture and Earthquakes in Istanbul; A Reconnaissance Report and Commentary on the performance of wooden structures in the Turkish earthquakes of 17 August and 12 November 1999" in April 2000. A version of this paper was also presented at the International Association for the Study of Traditional Environments, Trani, Italy, October, 2000. I would like to express my thanks those people who helped me with my research: Professor İhsan Mungan, Mimar Sinan University, Prof. Sami Kilic, Boğaziçi University, Prof. Mete Sözen, Purdue University, , Prof. Frederick Krimgold, Virginia Polytechnic Institute, Prof. Zeynep Ahunbay, İstanbul Technical University, Prof. Mustafa Erdik, Kandilli Observatory and Earthquake Engineering Institute, İstanbul, Prof. Fikret Yegul, University of California, Santa Barbara, Dr. Caroline Finkel, Arch. Turgut Cansever, Arch. Suphi Saatçi, Arch. Çelik Erengezgin, Orhan Esen, İnsan Yerlesimleri Derneği. I could never have completed my research without the help and companionship of Emre Özkan and Meltem Sahin, Research Assistants, Structural Engineering, Mimar Sinan University. Halil Sezen, at the Pacific Earthquake Engineering Research Center, UC Berkeley, and Sibel Zandi-Sayek, PhD candidate, Architecture UC Berkeley, helped in translating and finding contacts. Prof. Filip Filippou, Dept. of Civil Engineering, UC Berkeley, kindly looked over the manuscript. Last I would like to thank Mr. and Mrs. Cengiz Demirtas for an unforgettable dinner in a tent in the ruins of Düzce on the first evening of Ramadan.

[2] For reports on the earthquakes see the Kandilli Observatory web site, http://www.koeri.boun.edu.tr/earthqk/earthqk.html, "The İzmit (Kocaeli), Turkey Earthquake of August 17, 1999," EERI Special Earthquake Report, *EERI Newsletter*, 33:10, October, 1999, *Perspectives*, Degenkolb, November, 1999, *Newsletter*, Mid-America Earthquake Center, 2:2, October, 1999. Also see *Deprem Özel Sayısı, Cogito*, Istanbul, 1999, for commentary and discussion of the earthquakes.

[3] Turgut Cansever has begun to plan a new neighborhood of wooden houses on the outskirts of Istanbul. Mr. Cansever believes in an integrated strategy of low-rise wooden structures, as well as steel, reinforced concrete, brick and stone structures. Mr. Çelik Erengezgin of Bursa advocates traditional Turkish wooden architecture as well, however he endorses a wider use of wood for all types of buildings. Prof. Sadettin Ökten of Mimar Sinan University is simulating seismic loading of wooden members. Architects and engineers in Istanbul, considering the scope of the problem of poor reinforced concrete construction, are interested in solutions utilizing wood.

[4] The word "antiseismic," a translation of the Italian "antisismico," is used here to mean a structure which is designed to be seismically resistant.

[5] Although scholars are increasingly investigating historical earthquakes (as in H. Dursun, "İstanbul 'u seven katlanir depremine," Osman Köker, "Sansüre Uğramış, Bir Deprem, İstanbul, Adapazarı, İzmit, Yalova, 10 Temmuz 1894,"*Toplumsal Tarih*, 69, Eylül 1999, pp. 4-7, F. Ürekli, *İstanbul'da 1894 Depremi*, Istanbul, 1999, N. N. Ambraseys and C. F. Finkel, "The Saros-Marmara Earthquake of 9 August, 1912" *Earthquake Engineering and Structural Dynamics*, 15, 1987, pp. 189-211) there needs to be more emphasis on the history of antiseismic design (if it occurred). Extensive studies have been carried out on famous structures in Istanbul (as for example the work of R. J. Mainstone, "The Süleymaniye Mosque and Hagia Sophia ," *IASS Symposium on public assembly structures, Mimar Sinan University*, Istanbul, 1993, E. Mark, A.S. Çakmak, K. Hill, R. Davidson, "Structural Analysis of Hagia Sophia: a historical Perspective," A. S. Çakmak, R. Davidson, C.L. Mullen, M. Erdik, "Dynamic analysis and earthquake response of Hagia Sophia," and M. Erdik, E. Durukal, Ö. Yüzügüllü, K. Byen, U. Kadakal "Strong-motion instrumentation of Aya Sofya and the analysis of response to an earthquake of 4.8 magnitude," *Structural Repair and Maintenance of Historical Buildings III*, Bath, England, 1993, pp. 33-46, 67-84, 99-114) but everyday buildings need to be studied as well. Using contemporary observations and data Ambraseys and Finkel ("The Saros-Marmara Earthquake") discuss the performance of building types and the intensity of the earthquake in relation to future seismic threat. They are primarily interested in seismology, not engineering or building construction. Mustafa Armagan's *Alev ve Baton* (Istanbul, 2000) represents a promising new direction in research. It traces the history of the condemnation of the wooden house in the 1920s from a political standpoint. In San Francisco I have been attempting to create a context for understanding why and how antiseismic design was used. See my "A History of Reinforced Masonry Construction Designed to Resist Earthquakes: 1755-1907," *Earthquake Spectra*, Vol. 1, No. 1, November 1984, pp. 125-150. "Bond Iron and the Birth of Anti-Seismic Reinforced Masonry Construction in San Francisco, "*The Masonry Society Journal,* Vol. 5, No. 1, January-June 1986, pp. 12-18.. "Construzione anti-sismiche in muratura nella storia di San Francisco," *Costruire in Laterizio*, no. 15, May-June, 1990, pp. 191-196 Chapter 5, "How has architecture responded to earthquake challenges over time?" *Past, Present and Future Issues in Earthquake Engineering; Proceedings of the fiftieth annual meeting of the EERI*, 1998, pp. 9-12. pp. 13-23.

[6] D.Kuban, *The Turkish Hayat House*, İstanbul, 1995, p. 238

[7] Kuban *Ibid.*

[8] For earthquakes that struck Istanbul from the 16th through 18th centuries see Ambraseys and Finkel, *The Seismicity of Turkey*

[9] For destructive fires and attitudes towards them see D. Barilari and E Godoli, *Istanbul 1900, Art Nouveau Architecture and Interiors*, New York, 1996, p.79-82. Z. Çelik,*The Remaking of Istanbul, Portrait of an Ottoman City in the Nineteenth Century*, Berkeley, 1986, pp. 49-81

[10] Z. Çelik,*Ibid*. and Barilari and Godoli, p. 13

[11] For example see Çelik, p. 76.

[12] Ambraseys and Finkel, *The Seismicity of Turkey,* p. 144; document of 1766 in Zarif Ongun, "1509 (Hicrî) senesinde İstanbulu bastanbasa harab eden zelzelede sehri tamir için alınan tedbirler," *Arkitekt*, 1940, pp. 164-167.

[13] Ambraseys and Finkel, *The Seismicity of Turkey,* p. 93; İzmir continued to be a city of wooden houses until 1922 when it was burned during a battle between Greek and Turkish forces.

[14] On Lima and Lisbon see Charles Davis, "Shaking the Unstable Empire: The Lima, Quito, and Arequipa Earthquakes, 1746, 1783, and 1797" and Tobriner, "Safety and Reconstruction after the Sicilian Earthquake of 1693---the 18th century context," in *Dreadful Visitations, Confronting Natural Catastrophe in the Age of Enlightenment*, ed. Alessa Johns, New York and London, 1999, pp. 113-144 and 49-77.

[15] The building in question was the Grand Hotel in San Francisco. See "South Hall and Seismic Safety at the University of California in 1870," *Chronicle of the University of California*, 1: 1, 1998, p. 16.

[16] Köker, p. 6, Ürekli, pp. 40-54.

[17] Yet when newspapers published the opinions of the experts, architects wrote that the reason masonry had failed was that it was constructed by non-architects who knew nothing about good construction. Western-style masonry construction had survived, they argued, and begin a discussion of the best way of building masonry walls. Ürekli, *Ibid.*

[18] Kuban, p. 241

[19] Tobriner, "Safety and Reconstruction after the Sicilian Earthquake of 1693---the 18th century context," in *Dreadful Visitations, Confronting Natural Catastrophe in the Age of Enlightenment*, ed. Alessa Johns, New York and London, 1999, pp. 49-77.

[20] V. Cóias e Silva, "Um Novo modelo (e uma Nova Visão) do Edificado Pombalino," *Monumentos, Revista semestral de edificios e monumentos*, 6, March, 1997, 80-85.

[21] "La Casa Baraccata: Earthquake-resistant Construction in 18th Century Calabria," *Journal of Architectural Historians*, May 1983, XLII, No. 2, pp. 131-138. "La casa baraccata: un sistema antisimico nella Calabria del xviii secolo," *Per Costruire in Laterizio, antologia di saggii dalla rivista ufficiale*, ed. C. Latina, Rimini, 1999, pp. 203-209.

[22] See D. Upton, *Architecture in the United States*, Oxford, 1998, pp. 152-155 and pp. 307-309.

[23] For statements that wood was seismically resistant see: Tobriner, "South Hall and Seismic Safety at the University of California in 1870," *Chronicle of the University of California,* 1; 1, 1998.

[24] See P. I. Yanev, *Peace of Mind in Earthquake Country: How to Save Your Home and your Life*, San Francisco, 1974 and later editions.

[25] Günay, *Tradition of the Turkish House and Safranbolu Houses*, İstanbul, 1998, p. 66

[26] Although earthquakes do occur in Central Europe the cheapness of wood as opposed to masonry probably explains the popularity of timber framed buildings constructed in Germany in the late 16th through the 18th centuries. The half-timbered motifs of St. Andrew's cross, the Swabian wife, the Husband and the Half-husband can be seen in half-timbered churches especially in the area of Vogelsberg in Hesse, Germany. The intricacy of the exposed timber frames was extremely refined and contrasts markedly with the more casual timber frames of Turkish houses. See Förderkreis Alte Kirchen eds., *Fachenwerkkirchen in Hessen*, Königstein/Taurnus, 1987.

[27] For an introduction to English timber-framed buildings see R. Harris, *Discovering Timber-Framed Buildings*, Bucks (UK), 1978; also see bibliography in Upton, *Architecture in the United States, pp. 307-309*

[28] Günay, p. 93. Safranbolu has been studied extensively by a number of prominent scholars, including the dean of Turkish house studies, Sedad Eldem. I have relied most heavily on the work of Dogan Kuban and especially Reha Günay. I also visited Safranbolu and examined many of the features I discuss.

[29]My comments on configuration and buildings as well as hazards specific to wooden buildings are derived from many sources, among them *Buildings at Risk: Seismic Design Basics for Practicing Architects*, AIA/ACSA Council on Architectural Research, Washington, DC, 1994; C. Arnold and R. Reitherman, *Building Configuration and Seismic Design*, NY, 1982, and Yanev, *Peace of Mind in Earthquake Country.*

[30] Mr. Turgut Cansever believes that the negative assessment of masonry ground floors is too sweeping. These masonry walls can be antiseismic. He cites the example of the Muharrem Nuri Birgi house in Salacak, Istanbul, an 18th century wooden structure he restored in the 1970s which suffered no damage in the last two earthquakes.

[31] I interviewed Mr. Turgut Cansever in his office in December, 1999. At that time he drew the sketch illustrated here. Whether the nails were actually strong enough to provide a "moment" connection is still unclear. These nails or spikes are mentioned---disparagingly---in one 19th century document: "The frame, which is of very small dimension for the size of the building, is clumsily fastened together be large spikes" (J. De Kay, *Sketches of Turkey*,1831 and 1832, New York: 1833, quoted by Kuban, p. 239.)

[32] The comments which follow are based on my observation of wooden buildings during a reconnaissance trip to Turkey in December, 1999. Thus far no detailed evaluation of the performance of Turkish wooden architecture has appeared to augment my own. I focus on four sites, Kaynaslı and Düzce shaken in both earthquakes, but most badly on 12 November, and Ulaslı and Degirmendere which were damaged on 17 August.

[33] Barilari and Godoli, p.182

[34] M. H. Boduroglu, "Rural buildings in Turkey that have suffered damages in recent earthquakes and their main causes," *Bulletin of the International Institute of Seismology and Earthquake Engineering*, 23, 1989, p. 369.

[35] See E. Toby Morris, R. Gary Black, and Stephen Tobriner, "Report on the Application of Finite Element Analysis to historic Structures, Westminster Hall, London," *Journal of the Society of Architectural Historians* 54:3, September 1995, pp. 336-347.